EFFECTS OF LOW BAR AVOIDANCE AND GYMNAST SIZE ON HIGH BAR DISMOUNT PERFORMANCE

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INTRODUCTION

Required maneuver difficulty on the uneven parallel bars has increased with the maximum allowed bar spacing. Computer modeling, simulation and optimization are used to quantify the low bar's detrimental effect on the maximal number of dismount revolutions a short and a tall gymnast can complete. Two optimal low bar avoidance strategies were calculated; 1) using only planar shoulder and hip movement (2D), and 2) using planar shoulder but three dimensional hip motion (3D).

METHODS

A four-segment dynamic model of a female gymnast in a preparatory swing is optimized to maximize dismount revolutions at a specified landing height. The purpose is to quantify the low bar's effect on dismount performance and to calculate optimal joint motions for low bar avoidance resulting in minimum dismount performance decreases. Optimization constraints include maximal bar force, joint ranges of motion, and minimum landing distance. Joint torque models include angle, angular velocity, and isometric strength dependent factors. Torque activation time histories are approximated by cubic splines fit to ten nodes equally spaced throughout bar contact. Using the downhill simplex method, optimal joint torque activations and bar release time are calculated [1].

The optimal solution begins ($t = 0$) with the gymnast in a handstand rotating about the deflected bar with an initial angular velocity of 1.8 rad/s [2]. It ends at bar release (T), and results in maximal straight body revolutions during dismount:

$$J_o = (\omega(T)\Delta t + \gamma(T))/(2\pi) \qquad (1)$$

where $\omega(T)$ is the gymnast release angular velocity, Δt is the flight time and $\gamma(T)$ is the angle between the line from the deflected bar center to the gymnast mass center and vertical. Using the optimization criterion in eqn. (1) and constraints, three performances are calculated for two collegiate gymnasts: short=1.887m, 62.38 kg; tall=2.048 m, 69.30 kg.

RESULTS AND DISCUSSION

Both athletes completed the most revolutions when no low bar was present (Table 1). Avoiding the low bar and restricting motion to 2D decreased dismount performance 1.22% and 3.59% for the short and tall gymnasts, respectively (Fig.1). By straddling her legs, the performance decrease is reduced to 0.45% and 2.00%, respectively. The taller athlete with 2D motion was most affected by the low bar because her optimal swing was most altered to avoid low bar contact.

Table 1: Number of dismount flight revolutions

	No Low Bar	Low Bar	
		2D motion	3D motion
Short	1.556	1.537	1.549
Tall	1.503	1.449	1.473
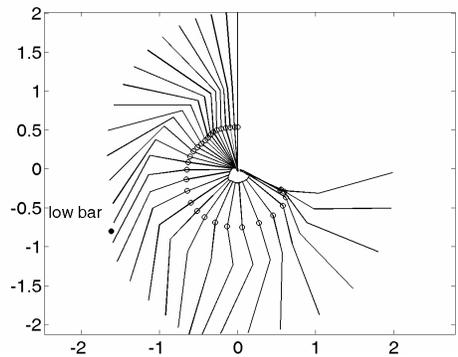
Figure 1: Stick figure sequence- tall 2D case

Absence of the low bar allowed more revolutions because joint torques applied during the swing added more energy to the system (Fig. 2). Avoiding the low bar required substantial negative work to resist hip joint extension after low bar clearance (Fig. 1), and decreased terminal system energy.
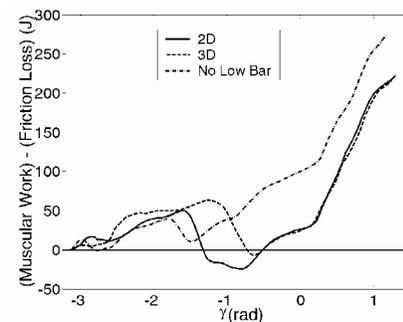
Figure 2: Net energy change during swing- tall gymnast

All performances were limited by the ability to maintain bar contact. Because the gymnast mass center cannot move instantaneously, fast joint angle flexion compresses the bar and exerts larger hand forces. Thus bar force constraints limit both joint angles and rates and, indirectly, ability to do muscular work.

In all cases, short athletes release with lower mass centers than tall ones. Short athletes minimize bar contact time because a larger percentage of initial energy is dissipated by bar friction (short-17%, tall-15%) reducing dismount performance capabilities. Frictional energy dissipation was relatively constant regardless of low bar presence. The short and tall athletes have largest release angles in the 2D case. Because of the time needed for joint extension after low bar avoidance, release is delayed to allow muscular work to be performed during bar contact.

REFERENCES

1. Nelder, JA & Mead, R. *Comp J*, 7, 308-313, 1965.
2. Hiley, MJ & Yeadon, MR. *J Appl Biomech*, 19(2), 119-130.