EVALUATING THE EFFECTS OF JAVELIN DESIGN ON JOINT FORCES AND TORQUES AND THE CONTROL OF THE RELEASE

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INTRODUCTION

A javelin thrower makes complex, multi-joint throwing movements that require great muscular strength, sophisticated coordination, and accurate javelin control. These movements develop the great forces necessary to accelerate the javelin to great release speeds, while carefully controlling the direction of the release [1]. Generating great forces exerts musculoskeletal stress on the upper extremity joints, which can cause acute and overuse injuries that lead to loss of training time, place a financial and quality of life burden on the javelin thrower, and may put them at an increased risk for secondary injuries. Greater masses and moments of inertia (MoI) of the limbs and javelin increase the magnitudes of the joint torques and forces, and the risk for injury [2]. The aerodynamic component of the distance thrown is the major difference between throwers at the elite level, and is primarily determined by the orientation and motion of the javelin at release. The javelin's mass and MoI affect the ease with which the release is controlled.

A newly designed training javelin, the Finnflier®, may have favorable mass and MoI characteristics for reducing injury and for training optimal control of the release. The purpose of this study was to evaluate the MoI of existing competition javelins and the Finnflier®, and to determine the effect of MoI on joint torques and forces, and the control of the release.

METHODS

Trials by 40 female and 40 male right-handed javelin throwers competing at various national meets were filmed with two high-definition digital video cameras at 59.94 Hz. The cameras were positioned with perpendicular optical axes. A 24-point calibration frame and global reference markers were also filmed for each meet. One trained and experienced researcher manually digitized 24 body and javelin landmarks to obtain 2-D coordinate data from the video clips. The Direct

Linear Transformation procedure [3] was used to obtain 3-D coordinates of the 24 landmarks.

Three competition javelins for women, three competition javelins for men, and the Finnflier® were evaluated. The length, mass, and center of mass location (COM) of each javelin were measured. The MoI for each javelin was calculated by suspending the javelin as a bifilar torsional pendulum. The Lagrangian equations of motion were linearized, and the pendulums were modeled as harmonic undamped oscillators. The MoI was calculated from the javelins' mass, the pendulum dimensions, and the angular velocity of the oscillations [4]. Cadaver data were used to calculate the mass, COM, and MoI of each body segment.

The release variables and orientation of the javelin were calculated using the 3-D javelin landmarks and the javelin reference frame [1]. Shoulder joint angles were calculated as Euler angles of an upper arm reference frame relative to an upper trunk reference frame (Figure 1). Elbow and wrist joint angles were calculated as the angles between the

longitudinal axes of the proximal and distal segments for those joints. The shoulder and elbow joint torques and forces were calculated using an inverse dynamic approach. The throwing arm was considered a four-link rigid segment model of the javelin, the hand, the forearm, and the upper arm. Joint forces and torques at the wrist, elbow, and shoulder were calculated in the global reference frame using an inverse dynamic procedure, and then transferred to the corresponding segment reference frames.

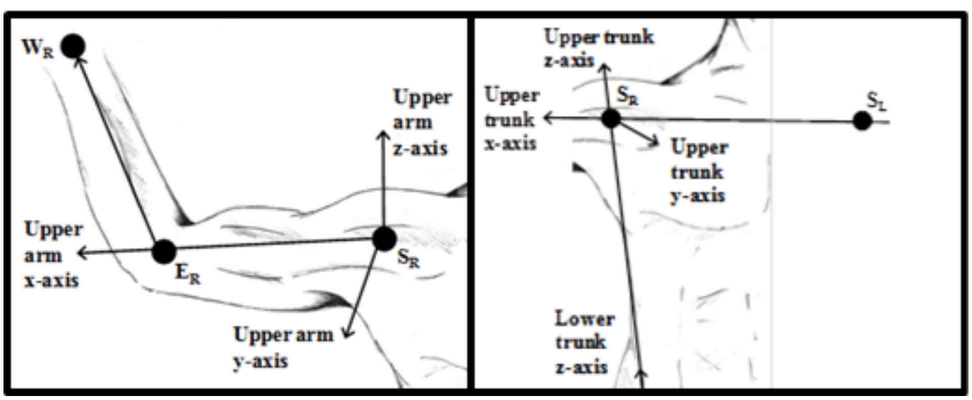

Figure 1: Reference frames for the upper extremity joint angles.
WR = right wrist, ER = right shoulder, SR = right shoulder, SL = left shoulder

RESULTS AND DISCUSSION

According to IAAF rules, competition javelins must be of standard length, mass, and COM. There was little variation in the MoI of the competition javelins: 0.5046 $kg.m^2$ and 0.7254 $kg.m^2$ for women and men, respectively. The Finnflier® was shorter (1.77 m), lighter (450 g), and had a COM similar to the women's competition javelin (0.78 m). The MoI of the Finnflier® was significantly smaller (0.1315 $kg.m^2$). The decrease in MoI is not proportional to the decrease in mass.

The decreased mass and MoI of the Finnflier® caused at least a twofold decrease in elbow varus torque, shoulder anterior shear force, and shoulder distraction force. These lower forces and torques represent a significantly lower risk for upper extremity injury. The decreased MoI also caused at least a fourfold increase in javelin angular velocity during the release. This increased forward rotation of the javelin represents a need for greater control of the release to gain aerodynamic distance and therefore official distance.

CONCLUSIONS

The decreased moment of inertia of the Finnflier® allows for training sessions with reduced risk of upper extremity injury, and a greater focus on control of the release.

REFERENCES

1. Best RJ, et al. *J Sports Sciences,* **11**, 315-328, 1993. 2.Andrews JR, & Fleisig GS. *J Orthop Sports Phys Ther*

27(3), 187-188, 1998.
3. Abdel-Aziz YI, & Karara HM. *ASP Symposium on Close*

Range Photogrammetry, Falls Church, VA, 1971. 4. Green MW. *NACA Technical Notes,* **265**, 18, 1927.