J.2 Throwlike Patterns: Sequential Segmental Rotations

The term throwlike, as used in this text, is characterized by movements used to project an object that is allowed to lag back behind the proximal segments that have finished their backswings and are now moving forward. The term **throwlike** refers to the characteristics of the general movement pattern of a throw and not to a throw per se. For example, a kick or a strike is classified as throwlike. In the case of striking activities, such as kicking or batting, the body part or the implement that will contact the object lags behind the other segments until just before contact, at which time it "whips" forward to catch up to its proximal segments.

The overall performance objective of these throwlike activities is either to project an object for the greatest horizontal or vertical distance, or to project an object for accuracy where the velocity of the object enhances its effectiveness. Regardless of which overall performance objective is appropriate, the velocity of the object at release is a most important variable. The velocity that an object will have at release depends on the velocity of the contact point that the object has with the hand, the foot, or the implement being used. So, in throwlike activities, we are attempting to achieve high "end-point" velocity.

The Open Kinetic Link Model

To illustrate how one may generate high end-point velocity with a system of segmented links, a model is shown in Figure J.1. The three segments are labeled **A, B,** and **C,** and the three axes of rotation for these segments are labeled **a, b,** and **c.** The arrows on segment **A** represent muscle torques applied to segment **A** and to a fixed "ground" segment. Because the muscle torques applied to segment **A** are external torques (i.e., external to the system of links), they can effect changes in the system's angular momentum. In the figure, the muscle torques between segments **A** and **B** and the muscle torques between segments **B** and **C** function as intersegmental torques and they are internal to the system. The way such a model functions can be understood by examining the following situation:

Suppose that the muscles to the right of segment **A** apply an external torque large enough to accelerate segment **A** in a clockwise (cw) direction. The intersegmental muscle torques between segments **A** and **B** and **B** and **C** work to resist the lagging back, or counterclockwise (ccw) motion of the distal segments relative to the proximal segment as the system

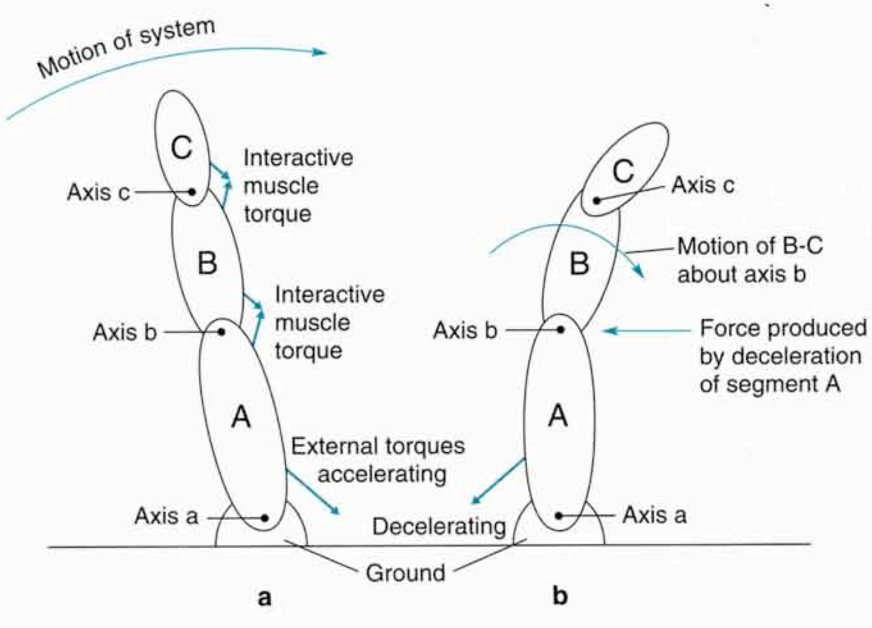

FIGURE J.1

A three-segment model of the kinetic link concept with external and internal torques influencing its motion.

accelerates cw. If these internal stabilizing torques were not applied, segments **B** and **C** would "lag back" as the distal end of segment **A** rotates forward. The external torques applied to segment **A** accelerate the entire system and give the entire system angular momentum.

Now suppose that a second external torque, the torque to the left of segment **A** and axis **a**, acts to decelerate segment **A** (Figure J.1b). The deceleration of segment **A** places a left-directed force on axis **b**, tending to "fix" that axis in space. Because segments **B** and **C** are free to move cw about axis **b**, **B** and **C** continue to rotate with the same angular momentum about axis **b**.

Because the axis of rotation for segments **B** and **C** has moved from axis **a** to axis **b**, the radius of gyration and thus the rotational inertia for the remaining moving system, segments **B** and **C**, has decreased. Consequently, because the momentum of the system is conserved and segments **B** and **C** are smaller masses and have a smaller radius of gyration about axis **b**, the angular velocity of segments **B** and **C** increases.

Note that the rotational inertia of the system decreased because the axis of rotation moved closer to the two end segments, resulting in a decrease in the radius of gyration as well as eliminating the mass of segment **A** from the system. Second, no external torque was applied to segments **B** and **C**, only to segment **A**.

Figure J.2 illustrates the application of the previously described model to a woman moving in a similar fashion. Each body segment moves by rotating around an imaginary axis of rotation that passes through the articulation of the segment. Recall that any point on any segment moves along a plane that is perpendicular to the axis around which it is rotating. Figure J.2 illustrates (1) the movement of the hand in space caused by flexing the pelvis and trunk at the hip joint around its mediolateral (ML) axis, Position 1 to Position 2; (2) the movement of the hand in space caused by the medial rotation of the abducted humerus around a longitudinal axis through the shoulder joint, Position 2 to Position 3; and (3) the hand movement caused by flexing the hand at the wrist around an ML axis, Position 3 to Position 4.

In this human body application of the model, segment **A** is accelerated by an external torque, which would be the hip flexors. This torque would give the entire system including segments **B** and **C** angular

FIGURE J.2

Flexion of the hip, medial rotation of the shoulder joint, and flexion of the wrist with all distal segments of the upper extremity fixed.