# INTERCEPTION AND INTERSEGMENTAL COORDINATION: EFFECTS OF PRACTICE

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There is general agreement that highly skilled throwers and strikers employ a sequential pattern of intersegmental coordination (Bunn, 1972; Kreighbaum & Barthels, 1990; Morehouse & Cooper, 1950). That is, "movements proceed from base to free end, from proximal to distal" (Kreighbaum & Barthels, p. 625) and "each [distal] segment comes forward as the movement of its proximal segment reaches its greatest angular velocity" (Kreighbaum & Barthels, p. 604). There is little agreement, however, concerning the coordination of less skilled throwers and strikers. According to Kreighbaum and Barthels, novice or immature performers typically display simultaneous or nearly simultaneous patterns of coordination (i.e., proximal and distal segments contribute to the movement at about the same time). In addition to the "optimal" sequential pattern of coordination, Morehouse and Cooper described two sub-optimal sequential patterns: the "early" pattern (i.e., distal segments initiate forward movement *before* proximal segments reach peak angular velocity) and the "late" pattern (i.e., distal segments initiate forward movement *after* proximal segments reach peak angular velocity). Further, Morehouse and Cooper stated that "hurrying the action is more detrimental to performance" (p. 125, 128) and "beginners usually have the fault of omitting some [segments]" (p. 128). Finally, Bunn (p. 42-43) hypothesized that "jerky movement instead of smooth rhythmic action" was associated with diminished effectiveness in throwing. Interestingly, none of these biomechanists addressed the contextual differences between throwing which is a closed skill (e.g., releasing a light object for high velocity) and striking which is an open skill (e.g., intercepting and propelling a light object for high velocity). Given that interception is a crucial component of many sports, the purpose of this study was to address the following questions: What pattern of coordination do smooth, sequential throwers exhibit in an unfamiliar interception task? How does this pattern of coordination change with practice?

## METHODS

The interception task for this study was the badminton smash. In contextual terms, this task is open (i.e., the performer does not control the direction or speed of the oncoming shuttle), the racket is light, the velocity demands are high, and the accuracy demands can be low. According to Gowitzke (1979), skilled smashers derive about 40% of shuttle velocity from long-axis rotation of the arm. In contrast, Kreighbaum and Barthels (1990) depict a beginning smasher with apparent shoulder flexion, little elbow extension, and excessive wrist flexion.

Four young adults who were experienced in throwing and other sports (e.g., swimming, track, racquetball, volleyball) served as subjects. They were unfamiliar with badminton prior to participating in a beginning badminton class. The first unit of the class lasted six weeks and emphasized the vigorous skills of underhand clear/serve, overhead clear, and smash.

Each subject was tested on the smash before (Week 0) and after (Week 6) the instructional unit. In each test session, the subjects performed ten smashes that were set up by the instructor. Because the assumption was made that the two primary components of the beginning smash would be shoulder and wrist flexion, a two-dimensional protocol was followed. Segmental end points were marked with reflective tape positioned at the hip, shoulder, elbow, and wrist joints, and the racket throat. The data were collected from the right side using a Panasonic video camera with a $^{1}/_{1000}$ second high speed shutter engaged.

The two best (i.e., most effective) trials from each testing session were chosen for analysis. Effectiveness of each smash was determined by the resultant angle and velocity of the shuttle and the placement of the smash in or out of bounds. Angular velocity of the shoulder and wrist were calculated using a Peak Performance 2D Motion Measurement System. The propulsive phase for each joint was defined as the time that angular velocity was positive and increasing. The pattern of coordination was determined from the relationship between the propulsive phases of the shoulder and wrist. Also, for certain trials, movements of the elbow and trunk were analyzed.

## RESULTS AND DISCUSSION

As there was little kinematic difference between the two best trials for a given subject in a given test session, only one trial per subject per session is presented in Figure 1. Before practice, Subject 1 employed a sagittal-plane striking technique with the elbow leading and the wrist/racket lagging. Although wrist velocity was greater than elbow velocity, both wrist and elbow joints were simultaneously involved during propulsion and peaked near contact. Based on its minimal angular velocity, the contribution of the shoulder appeared to be slight. After six weeks of practice, Subject 1 continued to use predominantly sagittal movements, but there was some apparent transverse adduction at the shoulder. In addition, the elbow lead was less obvious, and the shoulder velocity increased by a factor of two. The timing of the shoulder and wrist was "optimal," but the wrist was flexing faster before and after contact than at contact.

Subject 2 also demonstrated a sagittal smashing technique in Week 0. Overall, the range of motion was small and the greatest angular velocity was at the elbow joint. Also,

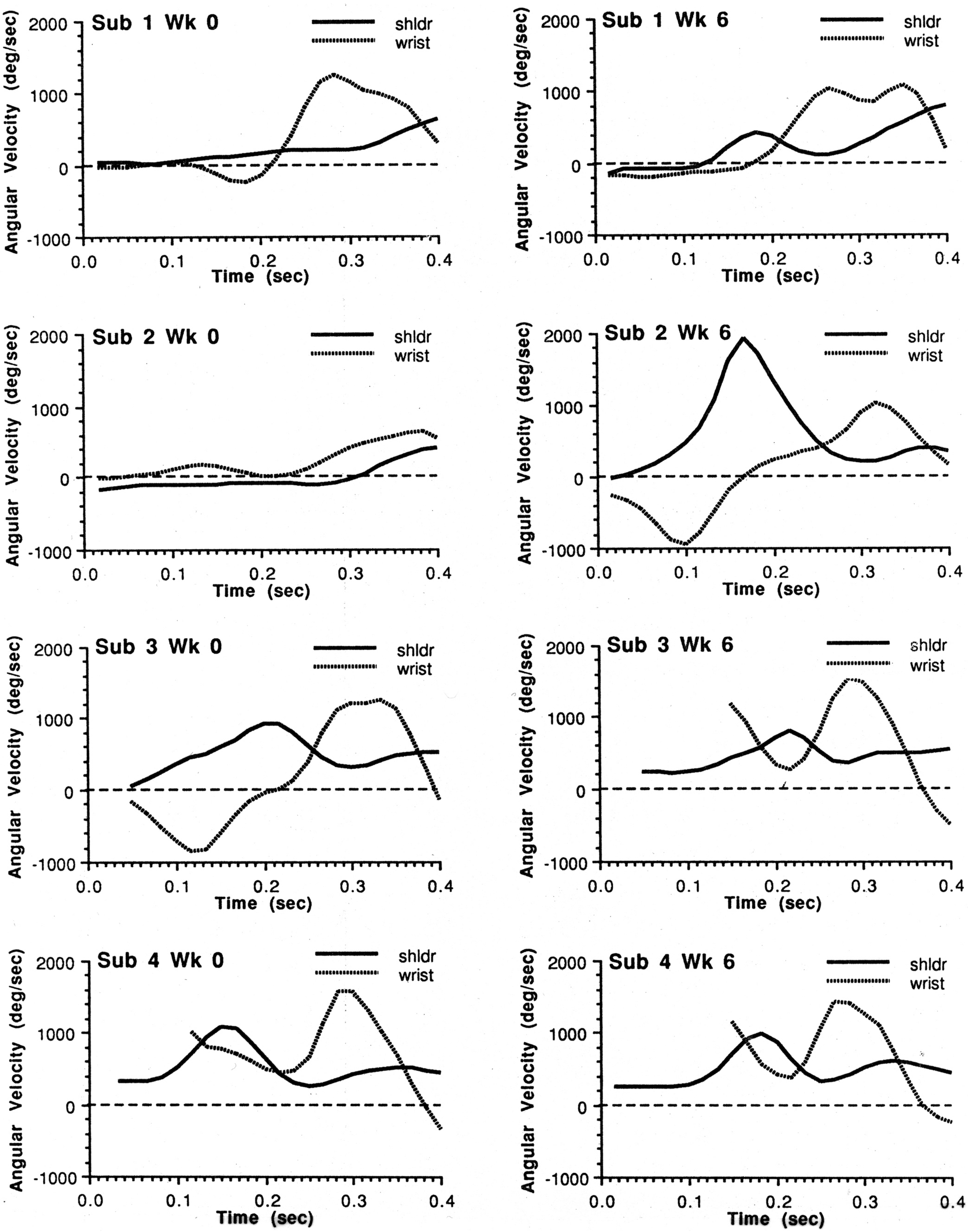


Figure 1. Angular velocity of shoulder and wrist before (Wk 0) and after (Wk 6) practice. Contact occurs at .3 sec.

there was slight shoulder extension rather than flexion during propulsion. Because the wrist velocity increased, then decreased, then increased again before contact, there was the appearance of "jerky movement." Subject 2 demonstrated profound changes with practice: Instead of "omitting" the shoulder, there was vigorous transverse adduction. Changes at the wrist included: initiation of rotation as the shoulder reached peak angular velocity, attainment of much higher angular velocity, and elimination of the appearance of jerkiness.

Prior to practice Subject 3 employed a striking technique that emphasized shoulder flexion but also included some long-axis rotation in the arm segments. The shoulder and wrist contributed to propulsion with optimal sequencing and timing. However, the wrist velocity stayed near maximum for a sustained period, and the trunk was translating throughout the swing. These wrist and trunk actions served to flatten the arc of the swing and appeared to be associated with interception. In Week 6 there was little modification of shoulder technique or timing. After practice, a preliminary back scratch motion was added, the wrist velocity was higher and more coincident with contact, the shoulder velocity was lower, and the trunk was stabilized during the arm movements.

Subject 4 in Week 0 exhibited similarities to the actions of Subject 3 in Week 6. For example, a back scratch movement proceeded the propulsive phase of shoulder flexion, and there was some long-axis rotation in the arm segments. Distinctive characteristics of Subject 4 included a gap of .07 s between peak angular velocity of the shoulder and minimum angular velocity of the wrist, and no "contact". That is, prior to practice, Subject 4 was unable to successfully intercept the shuttle. With six weeks of practice, Subject 4 made subtle changes in timing by reducing the gap between shoulder and wrist propulsion to .03 s. The only significant change with practice was that interception was consistently successful.

In conclusion, almost all the hypothesized characteristics of beginners were observed in Week 0: Subject 1 used a simultaneous pattern of coordination in the elbow and wrist (Kreighbaum & Barthels, 1990); Subject 4 used a "late" sequential pattern of coordination in the shoulder and wrist (Morehouse & Cooper, 1950); Subjects 1 and 2 virtually omitted the shoulder joint (Morehouse & Cooper); and Subject 2 used a "jerky movement" in the wrist (Bunn, 1972). After six weeks of practice all subjects had optimal or near-optimal sequential patterns of coordination in the shoulder and wrist.

Subjects 1, 2, and 3 appeared to adopt conservative patterns of striking in Week 0. That is, although they were successful in intercepting the shuttle, they reverted to sagittal-plane movement, propelled segments simultaneously, reduced range of motion, omitted segments, and/or flattened the arc of segments. Subject 4 neither exhibited these conservative characteristics nor contacted the shuttle. Perhaps interception adds a level of complexity to ballistic tasks such that initial success in making contact comes at the expense of more mature or coordinated movement.

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