The role of inter-segmental dynamics during catching in typically developing children and children with Developmental Coordination Disorder

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Catching is a skill that typically develops near 10 years of age, but children with Developmental Coordination Disorder (DCD) have difficulties performing this complex action. We examined whether improper joint coordination is a contributing factor to these difficulties. Nine typically developing (TD) boys and ten boys with DCD (ages of 9 to 12) attempted to catch 10 balls at eye level with their dominant arm. The arm was initially relaxed down at the participant's side with the hand semi-pronated. The movement required flexion of the shoulder and elbow and extension of the wrist in the para-sagittal plane, while the trunk remained motionless. Motion of the shoulder, elbow, and wrist was recorded. Amplitudes and directions of joint motions were similar in both groups. Net (NT), interaction (IT), gravitational (GT), and muscular torque (MT) was computed at each joint. Torque analysis revealed that the catching movement performed by the TD children usually included four phases (*Figure 1A*). In Phase 1, the shoulder and elbow simultaneously accelerated into flexion, and IT was suppressed by MT at both joints. This phase was brief, and only a small amount of NT was produced. In Phase 2, the elbow was accelerated into flexion primarily using MT, while IT and GT accelerated the shoulder into extension. In Phase 3, the shoulder accelerated into flexion using MT, while IT and GT accelerated the elbow into extension. During Phase 4, both joints were accelerated into extension mainly by GT. The children with DCD did not show the four-phase strategy of shoulder and elbow control. Instead, high variability in control strategies was observed, both within and across subjects, with a common tendency to suppress IT and accelerate-decelerate the shoulder and elbow simultaneously (*Figure 1B*) or not allowing IT to be utilized as effectively as in the TD children. In both groups, wrist MT consistently compensated for IT at this joint, resulting in low, fluctuating, but primarily extending NT. The results indicate that during catching, TD children use a complex strategy of shoulder and elbow control during which they sequentially accelerate each joint into flexion while allowing the other joint to be accelerated into extension passively, mainly by IT. Although this strategy was kinematically complex, the movements benefited from inter-segmental dynamics of the arm by avoiding suppression of IT and including it in movement production. In contrast, children with DCD tended to simplify movement kinematics, i.e. to accelerate and decelerate the shoulder and elbow into flexion simultaneously, which required suppression of IT by MT. These findings support optimal utilization of inter-segmental dynamics of the limb as a major organizing principle of multi-joint movement control. They also suggest ineffective exploitation of inter-segmental dynamics in children with DCD. The adequate joint displacements but not joint dynamics in children with DCD suggest a largely intact internal model of movement kinematics but not of movement dynamics. This finding supports previously proposed association of DCD with cerebellar deficiency.

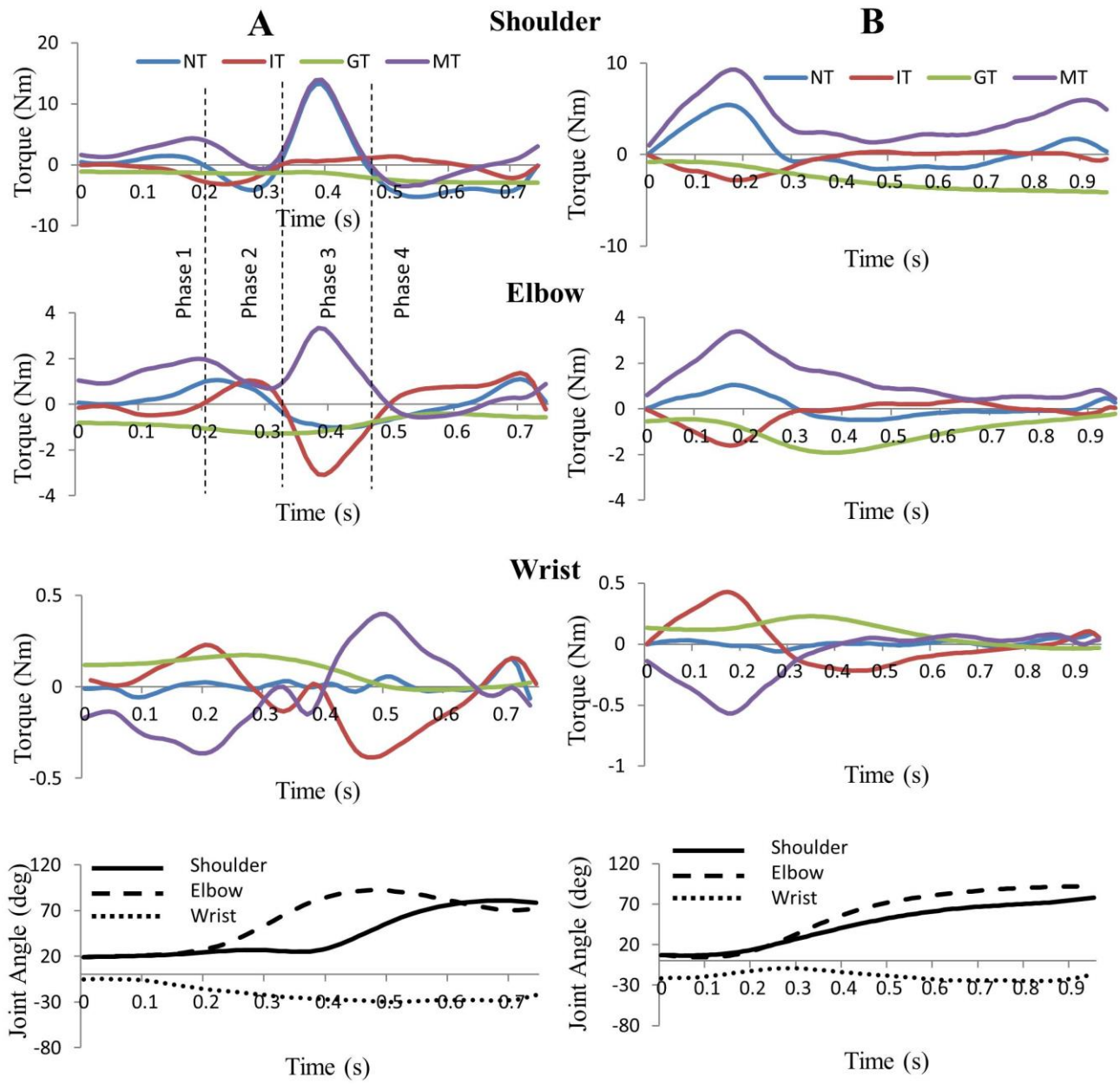

Figure 1. Individual angular displacements and torque profiles for the shoulder, elbow, and wrist joints. Profiles on the left are of a representative TD child, while the profiles on the right are of a representative child with DCD. The TD child performs the four-phase strategy. In Phases 2 and 3, where the majority of the movement occurs, the shoulder and elbow joint movements are segmented and while one joint is accelerated into flexion under active control, the other joint is passively accelerated via IT and GT in the opposite direction. This trend is not present in the child with DCD, as this child accelerates each joint in the same direction and in turn has to suppress passive rotation due to IT and GT.