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Full Length Article

Contribution of interaction torques during dart throwing: Differences between novices and experts

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ABSTRACT

We examined if experts and novices show different utilization of the torque components impulses during dart throwing. Participants threw darts continuously at a dartboard aiming for the centre (target bull's eye). The upper-limb joint torque impulses were obtained through inverse dynamics with anthropometric and motion capture data as input. Depending on the joint degree of freedom (DOF) and movement phase (acceleration and follow-through), three main strategies of net torque (NET) impulse generation through joint muscle (MUS) and interaction (INT) torque impulses were highlighted. Firstly, our results showed that the elbow flexion–extension DOF leads the movement according to the joint leading hypothesis. Then, considering the acceleration phase, the analysis revealed differences in torque impulse decomposition between expert and novices. For the glenohumeral (GH) joint abduction–adduction and for wrist flexion, the INT torque impulse contributed positively to NET joint torque impulse in the group of experts unlike novices. This allowed to lower the necessary MUS torque impulse at these DOFs. Also, GH axial rotation was actively controlled by muscle torque impulse in the group of experts. During the follow-through, the experts used the INT torque impulse more proficiently than novices to break the elbow extension. The comparison between experts and novices through inverse dynamics document the link between the exploitation of interaction torques impulses and expertise in dart throwing for which the main objective is precision rather than velocity.

1. Introduction

Depending on the sport discipline, the goal and the optimized biomechanical variables differ. In overarm throwing, the effective utilization of the non-muscular interaction torques (INT) which strongly depends on the throwing phase (Hansen, Rezzoug, Gorce, Venture, & Isableu, 2016) is a key factor in creating dynamic limb motion to maximize hand velocity (Hirashima, Kudo, Watarai, & Ohtsuki, 2007; Hirashima, Yamane, Nakamura, & Ohtsuki, 2008; Kinoshita et al., 2017; Naito & Maruyama, 2008; Neal, Snyder, & Kroonenberg, 1991; Timmann, Lee, Watts, & Hore, 2008). Studies considering 2D models have shown that INT at the elbow, due to proximal joint movements and torques, contributes to its acceleration while INT is counterbalanced at the wrist by the muscle torque (MUS) to precisely control the timing of ball release (Hirashima, Kudo, & Ohtsuki, 2003; Hirashima, Ohgane, Kudo, Hase, & Ohtsuki, 2003). Other studies considering 3D modeling and skilled baseball players revealed the presence of flexion INT at the wrist due to trunk and shoulder movements and muscles torques (Hirashima et al., 2007). Moreover, the braking of the shoulder

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movement contributes to elbow acceleration and late INT at the elbow helps braking its movement (Debicki, Watts, Gribble, & Hore, 2010; Hore, Debicki, Gribble, & Watts, 2011). This contribution of INT is also important during movements such as reaching executed at self selected speed (Yamasaki, Tagami, Fujisawa, Hoshi, & Nagasaki, 2008). Therefore, the question arises if INT can be a marker of expertise in throwing activities such as dart throwing for which maximal velocity is not the primary objective. Previous work has shown that practice is associated with reduced movement variability and a decrease of cross-correlation between shoulder and elbow angular displacements (McDonald, van Emmerik, & Newell, 1989). The modification of joint angle variability over time (decrease of non-goal equivalent and goal equivalent variances) was also shown using the uncontrolled manifold hypothesis (Yang & Scholz, 2005). The experts minimize velocity errors (Smeets, Frens, & Brenner, 2002) and have either a longer release window to accurately throw a dart using the appropriate hand trajectories or very low timing errors compared to novices (Nasu, Matsuo, & Kadota, 2014). Also, no significant difference in performance nor consistency have been found according to the time of day for standard throws performed at a distance of 2.37 m from the target (Edwards, Waterhouse, Atkinson, & Reilly, 2007). Only few studies have investigated the dynamics of dart throwing and especially the possible link between INT exploitation and expertise. It has been shown that INT at the elbow is positively correlated with performance highlighting the importance of dynamic interaction (Tamei, Obayashi, & Shibata, 2011). However, this study included only four subjects (2 skilled and 2 novices) and further investigation is needed to study this possible relationship more thoroughly.

In this framework, we examined the variations of the underlying dynamics with novice and expert dart players under regular conditions using optical motion capture. We hypothesized that experts, in contrast to novices, make use of INT impulse generated by the elbow and shoulder joints, to contribute to 1) the NET torque impulse at the wrist to control its flexion and 2) to decrease MUS impulse at the shoulder degrees of freedom (DOF).

2. Methods

2.1. Participants

Eight male novice participants (mean = 24, sd = 2 years; mean = 1.80, sd = 0.05 m; mean = 73, sd = 8.8 kg) and thirteen expert male dart players (mean = 34, sd = 10 years; mean = 1.80, sd = 0.08 m; mean = 90.5, sd = 18.2 kg) were recruited to participate in the experiment. All participants were right handed according to the Edinburgh handedness questionnaire (Oldfield, 1971) and voluntarily took part in the experiment after signing a statement of informed consent pertaining to the experimental procedure which was approved by the EA 4532 local Ethics Committee as required by the Helsinki declaration (World Medical Association, 2013). Participants were free of sensory, perceptual, and motor (shoulder, elbow, and wrist) disorders and naïve to the purpose of the experiment. The novice subjects had no specific experience of dart throwing and had only played darts a few times before while the experts were competitors in the French dart throwing championship. Their experience playing darts ranged from four to twenty years. The data of one novice subject were withdrawn from the analysis due to technical problems during the recording session.

2.2. Instructions

According to the World Darts Federation rules, the horizontal distance between the front of the board and any part of the shoes was at least 2.37 and the centre of the board (the target bull's eye) was 1.73 m above the floor. The novice dart players performed the task with the same competition standard darts (18 g) and no manipulation or instruction was given on how the task should be performed except that the general throwing posture and technique should not vary throughout the trials. The experts on the other hand played with their personal darts to avoid perturbations in their performance. Following a 10-min warm-up, each subject was instructed to perform 10 dart throws repeatedly aiming for the target bull's eye. Before the recording session, novices performed ten rounds of three darts to the board resulting in 30 throws, while the experts judged their readiness within the given time limit. For the experts, the data collection took part during the French Open and participants were free to "walk in" between their games. No specific time constraints were put on the players but data collection was between 10.00 am and 5.00 pm. The novices (students) were asked to perform the experiment during university day and data collection was between 09.00 am and 5.00 pm.

2.3. Movement phases

The dart throwing motion consists of four phases: the aiming, the backward move, the acceleration and the follow through. The aiming consists in focusing on the target. It is followed by the backward move during which the elbow is slightly flexed. At the end of this phase, the upper limb joint velocities are equal to zero. The beginning of the acceleration phase coincides with the reversal from flexion to extension at the elbow joint and it ends with the instant of dart release (ToR) (Hansen, Rezzoug, Gorce, & Isableu, 2012). The follow-through corresponds to the end of the arm movement during which the articular movements of the joints are decelerated and then stopped. In this paper, the analysis was focused on the acceleration and the follow-through phases.

2.4. Performance measure

The position of the dart on the target was ranked from 1 to 10 according to its vicinity with the target bull's eye. The scores of the ten throws were averaged.