O95-Which axes of rotation are employed during fast and slow motions of the dominant and non-dominant arms?

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The velocity-dependent change in rotational axes observed in the control of unconstrained 3D arm rotations for the dominant limb seems to conform to a minimum inertia resistance (MIR) principle (Isableu et al., 2009). This is an efficient biomechanical solution that allows for the reduction of torques during manual activity. We tested whether the MIR principle governs rotating movement when subjects were instructed to maintain the shoulder-elbow joint axis close to horizontal for both dominant and non-dominant limbs. Subjects (n=12) rotated their arms in two angular velocities, slow (S) versus fast (F), and in two vision conditions, eyes open (Op) versus eyes closed (Cl).The elbow remained flexed at 90° to yield a constant separation between the rotation axes of minimum inertial resistance (e_3), minimum centre of mass rotation (shoulder-centre of mass, SH-CM) and minimum joint rotation (shoulder-elbow, SH-EL). We hypothesized that visual cues (Op) should help the subjects maintain rotation around SH-EL, while kinaesthetic cues alone (Cl) should facilitate rotation around e_3. We expected more scattered displacements of the rotation axis employed for rotating the non-dominant limb compared to the dominant limb. The results showed that the rotational axis of a multi-articulated limb coincided with SH-EL at S & F velocity for both arms. These results provide evidence that instructions regarding limb orientation affect the exploitation of efficient biomechanical solutions for both dominant and non-dominant limbs.

INTRODUCTION

Daily activities and skilled athletic performance requires the control of complex 3D rotational movements of the upper limbs within different ranges of angular acceleration, mainly with the dominant arm and often in the absence of visual feedback. A nontrivial observation is that during most unconstrained three-dimensional (3D) movements an exact correspondence between the rotation axes of minimum inertial resistance (e_3), minimum centre of mass (shoulder-centre of mass, SH-CM) and minimum joint rotation (shoulder-elbow, SH-EL) very seldom occurs (Hirashima et al. 2007b; Hirashima et al. 2007a; Isableu et al. 2009). For the dominant limb, Isableu et al., (2009) observed a velocity-dependent change in rotational axes away from the SH-EL axis during the kinaesthetic control of unconstrained 3D arm rotations. We questioned whether this change applies to the non-dominant arm as well as the dominant arm and if it applies when the initial starting position of the arm is strictly defined. Earlier studies have shown a dominant limb advantage in the control of interaction torque during a variety of tasks (Sainburg, 2002; Dounskaia, 2005).

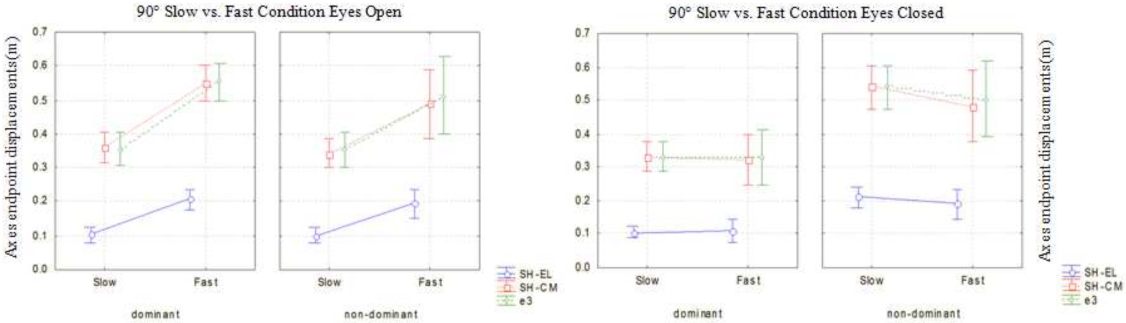
METHODS

12 subjects voluntarily participated in the experiment after signing a statement of informed consent as required by the Helsinki declaration and the EA 4532 local Ethics Committee. The limb dominance of the subjects was determined using a 10-item version of the Edinburgh Handedness Inventory. Ten were right handed and two were left handed.. During separate trials the subjects rotated their dominant & non-dominant arm with the elbow flexed at 90° to yield a constant separation between the SH-EL, SH-CM and e_3 axes (for more details see Isableu et al., 2009), according to two angular velocities, S (0.1Hz) versus F (2.0Hz), and two visual conditions, eyes open (Op) & versus eyes closed (Cl). The initial shoulder elevation of 90° was always adopted before each trial (i.e., SH-EL axis close to horizontal). A V8i VICON eight camera (Mcam2) motion capture system was used to record arm movements at a rate of 250 Hz (Vicon motion systems Inc., Oxford, UK).

RESULTS AND DISCUSSION

A three way MANOVA combining arm velocity (S vs F) with arm dominance and the two visual conditions showed no significant main effect for arm velocity on the variability of endpoint displacements of SH-EL, SH-CM or e_3 (Lambda Wilk =.75, $F(3, 9)=1.00$, $p=.43$). Thus, the increase in velocity did not yield a consistent change in the axes around which the whole arm was rotated (see figure 1).

Figure 1: Variations of endpoint displacements of rotation axes elicited by the velocity increase (Slow vs. Fast) and arm dominance (dominant vs. non dominant) in eyes open (left) or eyes closed (right) conditions.



Subjects maintained the rotation of their arms around the shoulder-elbow axis (SH-EL). The velocity x arm dominance interaction was not significant for either of the two vision conditions. We observed similar endpoint displacement patterns between the dominant and the non dominant arm except in eyes closed condition where endpoint displacements of the SH-EL axis were less scattered ($p<.05$ using Bonferroni correction). We also observed that endpoint displacements became significantly more scattered in the fast eyes open condition for both the dominant ($p<.05$) and non-dominant arms ($p<.05$).

CONCLUSIONS

Our results provide evidence that instructions pertaining to how a limb is to be moved may prevent individuals from exploiting the most efficient biomechanical solutions like the MIR principle, and this holds true for both the dominant and the non dominant limbs. The rotation around the SH-EL axis was maintained in the slow and fast velocity conditions, even though the e_3 axis provides an optimal minimisation of inertial resistance. These findings shed light on the ability of subjects to maintain kinematic patterns of motion despite dynamic forces that conflict with those patterns, a skill that is very important in applications such as throwing and hitting athletic activities. The findings also show that kinaesthetic cues alone can reduce the endpoint displacements of the SH-EL axis, mainly for the dominant arm. Our data differ from previous research that showed different strategies during tasks that generally involved maximal endpoint precision (Sainburg, 2002), high frequencies and different initial starting positions/postures (Isableu et al., 2009).

REFERENCES

Dounskaia N. The internal model and the leading joint hyothesis: implications for control of multi-joint movements. Exp Brain Res. 166:1-16. 2005.

Hirashima M, Kudo K, Ohtsuki T (2007a) A new non-orthogonal decomposition method to determine effective torques for three-dimensional joint rotation. J Biomech 40:871-882

Hirashima M, Kudo K, Watarai K, Ohtsuki T (2007b) Control of 3D limb dynamics in unconstrained overarm throws of different speeds performed by skilled baseball players. J Neurophysiol 97:680-691

Isableu B, Rezzoug N, Mallet G, Bernardin D, Gorce P, Pagano CC (2009) Velocity-dependent changes of rotational axes in the non-visual control of unconstrained 3D arm motions. Neuroscience 164:1632-1647

Sainburg R. Evidence for a dynamic-dominance hypothesis of handedness. Exp Brain Res. 142:241-258. 2002.