BIO Web of Conferences 1, 00032 (2011)
DOI: 10.1051/bioconf/20110100032

Do axes of rotation change during fast and slow motions of the dominant and non-dominate arms?

Clint Hansen* Nasser Rezzoug*† [2]Philippe Gorce*† Christopher Pagano‡ Brice Isableu*
(*)Univ. Paris-Sud. URCIAMS – Motor Control & Perception team, Orsay F-91405, France
(†)[2]Univ. du Sud – Toulon Var, HandiBio, EA 4322, La Garde F-83957, France*
(‡)Clemson Univ. Department of Psychology, Clemson, SC 29634, USA
E-mail: Clint.Hansen@u-psud.fr, rezzoug@univ-tln.fr, gorce@univ-tln.fr

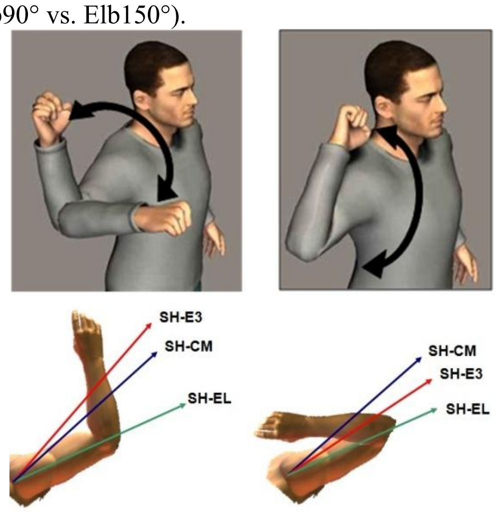
Abstract

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 [4]. This is an efficient biomechanical solution that allows for the reduction of torques. 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) performed external-internal rotations of their arms in two angular positions (90° versus 150°), two angular velocities (slow (S) versus fast (F)), and in two sensory conditions (kinaesthetic (K) versus visuo- kinaesthetic (VK)). 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.

1. Introduction

Daily activities and skilled athletic performance require 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. Recent research [5] showed differences in the dynamic intersegment control in between the dominant and the non-dominant arm and especially that the adaption for new tasks was less effective for the non-dominant limbs. Earlier studies have also shown a dominant limb advantage in the control of interaction torque during a variety of tasks [5], [1]. 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 movement (shoulder-centre of mass, SH-CM) and minimum elbow movement (shoulder-elbow, SH-EL) very seldom occurs[2],[3],[4]. For the dominant limb, [4] a velocity-dependent change in rotational axes away from the SH-EL axis during the kinaesthetic control of unconstrained 3D arm rotations was reported which acted favourably on the interaction torque to decrease the necessary muscle torque. We questioned whether this change in rotational axes 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.

Figure 1: Orientation of SH-CM and e_3 axes relative to the SH-EL axis as a function of arm configurations (Elb90° vs. Elb150°).



2. Methods

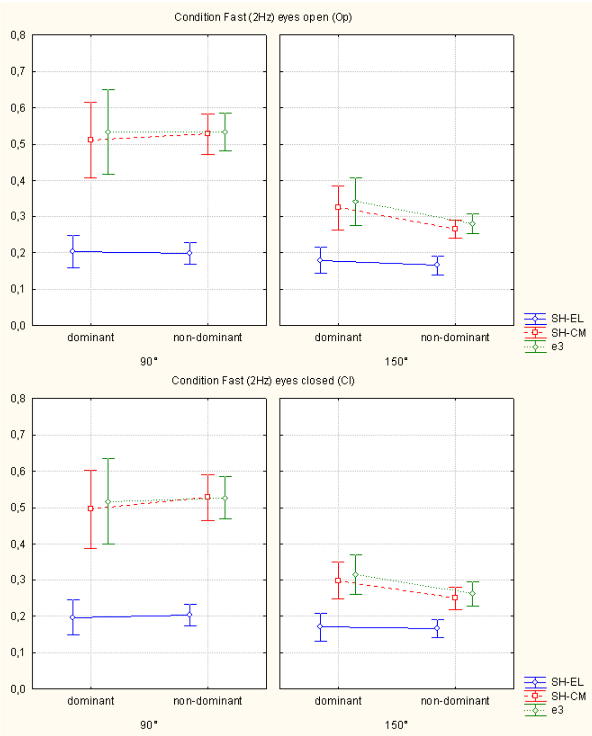
12 subjects voluntarily participated in the experiment after signing a statement of informed consent as required by the Helsinki declaration and the EA 4532 local Ethics Committee. The limb dominance of the subjects was determined using a 10-item version of the Edinburgh Handedness Inventory. Ten were right handed and two were left handed. During separate trials the subjects rotated their dominant & non-

dominant arm with the elbow flexed at 90° or 150° to yield a constant separation between the SH-EL, SH-CM and e_3 axes (for more details see [4]), (see figure 1) according to two angular velocities, S (0.1Hz) versus F (2.0Hz), and two sensory conditions, visuo-kinaesthetic (VK) with eyes open & versus kinaesthetic (K) with eyes closed. Each subject performed both of the elbow conditions at each of the two velocities three times for a total of 24 trials. The three trials for a given elbow configuration, frequency and optical constraint were presented in succession within a single block, with a 30 s rest period between each trial. The eight blocks of trials were performed in a random order, with a one minute rest period between them. Subject were instructed to maintain the initial shoulder elevation of 90° before and during 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).

3. Results

A four by 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 =.47, $F(3, 9)=3.38$, $p=.07$). Thus, the increase in velocity did not yield a consistent change in the axes around which the whole arm was rotated (see figure 2).

Figure 2: Variations of endpoint displacements of rotation axes elicited by the sensory change (VK vs. K) and arm dominance (dominant vs. non dominant) in fast (F) 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 different endpoint displacement patterns between the eyes open and closed condition for the dominant arm in both velocity and for the non-dominant arm in eyes open condition ($p<.05$ using Bonferroni correction). We also observed that endpoint displacements of the SH-EL axis became significantly more scattered in the fast VK & K sensory conditions for both the dominant ($p<.05$) and non dominant arm ($p<.05$) in the 90° angular condition. We found that endpoint displacements of the SH-EL axis became significantly more scattered in the fast VK & K sensory condition for the non-dominant ($p<.05$) but not for the dominant arm in the 150° angular condition. During the slow condition the results showed that there is a difference between the dominant and the non-dominant arm concerning the endpoint displacement of the axes. The vision x arm dominance interaction is significantly different for this condition ($p<.05$).

4. Discussion

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 sport activities such as throwing and hitting and in artistic expression such as dance. The findings also show that kinaesthetic cues alone can reduce the endpoint displacements of the SH-EL axis. Our data differ from previous research that showed different strategies during tasks that generally involved maximal endpoint precision [5] high frequencies and different initial starting positions/postures [4].

5. References

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

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

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

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

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