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Full Length Article

Three-dimensional kinematics of upper limb anatomical movements in asymptomatic adults: Dominant vs. non-dominant

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ABSTRACT

The effect of dominance on upper limb (UL) kinematics has only been studied on scapular movements. Moreover, when an anatomical UL movement is performed in a specific plane, secondary movements in the remaining planes involuntarily occur. These secondary movements have not been previously evaluated. The aim of this study was to compare the kinematics of primary and secondary angles of dominant and non-dominant UL during anatomical movements in asymptomatic adults.

25 asymptomatic adults performed 6 anatomical movements bilaterally: shoulder flexion-extension, abduction-adduction, horizontal abduction-adduction, internal-external rotation, elbow flexion-extension and wrist pronation-supination. Kinematics of the dominant and non-dominant UL were compared by their ranges of motion (ROM) and their angular waveforms (Coefficient of Multiple Correlations, CMC).

The comparison between dominant and non-dominant UL kinematics showed different strategies of movement, most notably during elbow flexion-extension (CMC = 0.29): the dominant UL exhibited more pronation at maximal elbow flexion. Significant secondary angles were found on most of the UL anatomical movements; e.g. a secondary ROM of shoulder (humero-thoracic) external-internal rotation (69° ± 16°) was found when the subject intended to perform maximal shoulder abduction-adduction (119° ± 21°).

Bias of dominance should be considered when comparing pathological limb to the controlateral one. Normative values of primary and secondary angles during anatomical movements could be used as a reference for future studies on UL of subjects with neurological or orthopedic pathologies.

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1. Introduction

The Upper Limbs (UL) can be affected by trauma, inflammatory diseases or degeneration among other etiologies. These pathologies can alter the normal function of muscles, tendons or joints and in consequence change the normal three-dimensional (3D) movement patterns of the different joints of the UL (Millett, Giphart, Wilson, Kagnes, & Greenspoon, 2016; Shinohara et al., 2014). Thus, knowledge of the normal motion of the upper extremities in 3D is essential in the assessment of UL affections and in treatment evaluation.

There is no single movement which is of particular importance to the study of the upper limbs. Ranges of Motion of the UL would be best evaluated by anatomical movements of the UL joints, such as flexion-extension, abduction-adduction and internal-external rotation which are primarily performed in one plane. Since each of the UL joints have more than one degree of freedom during each of the movements, involuntary movements could occur in the two remaining planes and are usually referred to as secondary movements. It would be clinically relevant to investigate which secondary movements (the second and third angles of the Euler or Cardan sequences) are performed during the execution of the full ROM in the primary plane.

Furthermore, in most of the clinical studies, the kinematics of a pathological limb is compared to those of the controlateral limb (Roren et al., 2012). Thus, it is essential to quantify the kinematic differences between normal dominant and non-dominant UL. The effect of dominance has only been studied on scapular kinematics (Lee, Yang, Kim, & Choy, 2013; Matsuki et al., 2011; Schwartz et al., 2014). These differences have still not been explored in the other joints of the UL.

The aim of this study is to compare the kinematics of both the primary and secondary planes of anatomical movements between the dominant and non-dominant UL in an asymptomatic adult population.

2. Methods

2.1. Population

Twenty five healthy adults (13 females, 12 males) with a mean age of 28.7 ± 7 (mean ± 1SD), from the institution where the motion capture laboratory is installed, had voluntarily participated in this study. Twenty one subjects identified themselves as right-handed and four as left-handed. All Participants had no history of musculoskeletal or neurological impairments. Written informed consent was obtained from all participants. The Institutional Review Board of the Hotel-Dieu de France Hospital/University of Saint-Joseph approved the study design.

2.2. Experimental protocol

The participants were seated at a height-adjustable chair with lower back support, hips and knees flexed at 90° and both feet flat on the ground. The subjects were instructed to keep their backs in their physiological postures. No physical restraints were used in order to avoid affecting the normal movement of the upper limbs. Each task was explained and tested before the acquisition. The participants were asked to perform anatomical movements of the UL. All movements were tested bilaterally and repeated 3 times by each UL. Twelve randomly selected participants (3 females, 9 males) were evaluated on two occasions, by the same operator, with at least one week interval in order to assess measurement repeatability.

Participants were asked to minimize trunk movement as much as possible and to reach the maximum range of motion possible. The anatomical movements consisted of:

1. Shoulder flexion-extension: the participants started with their arm positioned vertically beside their trunk, in a relaxed position with their palm in the neutral position (palm in the parasagittal plane). Then, they were asked to perform complete flexion followed by complete extension of the shoulder and to return to the starting position (movement mainly in the sagittal plane).
2. Shoulder abduction-adduction: from the same starting position, the participants had to move their UL laterally (movement mainly in the frontal plane).
3. Shoulder horizontal abduction-adduction: the UL is held at 90° of abduction as a starting position. A horizontal adduction (moving the UL, elbow extended, to the opposite shoulder) followed by a horizontal abduction is performed; from the starting position backward while keeping a 90° angle with the trunk (movement mainly in the horizontal plane).
4. Shoulder internal-external rotation: from 90° of abduction of the shoulder and 90° of flexion of the elbow (pointed forward) we asked the participants to perform an internal rotation of the shoulder (moving the palm of the hand downward and backward) followed by the external rotation (moving the palm of the hand upward with the palm facing forward): the humerus is rotated around the lateral axis passing by the 2 shoulders.
5. Elbow flexion-extension: same starting position as in task 1. We asked the participants to perform complete flexion of the elbow followed by complete extension.
6. Hand pronation-supination: the arm positioned vertically beside the trunk with 90° of flexion of the elbow and with the thumb pointing upward. The participants were asked to move their palm downward (pronation) and upward (supination).

The anatomical movements were illustrated in Fig. 1.