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Modified vector coding analysis of the shoulder and elbow joints coordination during arm-jump test

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1. Introduction

The arm-jump is an upper limb test to quantify the climbers upper body capacities (Laffaye et al., 2014). This movement involves a complex coordination through the upper limb joints but it has not been studied looking at the shoulder and elbow simultaneous coordination. The vector coding technique is used in biomechanics to analyse and quantify the coordination of segmental limbs movements. It addresses the angle-angle plot of two joint angles, to calculate vector to represent the direction and magnitude of the coordination. The analysis of this vector allows to easily understand the segmental coordination involving two adjacent joints. Vector coding is used to quantify complex sport motion such as back squat (Maddox et al., 2020) or rear-foot and fore-foot coordination (Chang et al., 2008). Modified vector coding allows to classify the coupling angle using the projected angles on the frontal, sagittal and transverse planes.

This abstract aims to investigated the shoulder and elbow joint coordination strategy, during an arm-jump test, using a modified vector coding technique.

2. Methods

2.1 Participants

Seventeen skilled climbers over 7c French route grade were involved in the study.

2.2 Protocol

From a hanging standardized position on two ladder rungs as hand holds, subjects were asked to jump as high as possible with both hands simultaneously. Each climber was asked to stabilize the posture before starting the movement, with engaged shoulder and slightly bent arm (around 120°). The study design was approved by the Ethics Committee CERSTAPS (IRB00012476-2023-18-07-262).

2.3 Material

Twenty-seven retroreflective markers were positioned on the body according to the ISB recommendations (Wu et al., 2005) on both side: ulnar styloid process, olecranon, tip of the acromion process, spinous process of C7, anterior superior iliac spine. Markers were

detected by thirteen Qualisys cameras (ARQUS). The optoelectronic sampling rate was 225 Hz.

2.4 Movement description

The study focuses on the shoulder and elbow joints which are mainly involved in the pulling movement. The elbow flexion/extension refers to the decrease/increase of the angle between the forearm and the upper arm. For the shoulder joint, three movements are considered with angles relative to humeral rotation:

- Shoulder extension/flexion in the sagittal plane moves the arm closer to/away from the body.
- Shoulder adduction/abduction in the frontal plane moves the arm closer to/away from the body
- Shoulder axial rotation around the humerus axis, as described by (Wu et al., 2005) (see section 2.3.5) involves medial/lateral rotation, moving the humerus closer to/away from the body.

The different planes are computed from the kinematic markers. The frontal plane is formed by the axis defined by the acromion and the anterosuperior iliac spine markers. The sagittal plane is orthogonal to the frontal plane with the axis formed by the anterosuperior iliac spine and the acromion markers. Additionally, the angle formed by the normal vector to the plane defined by the acromion, olecranon, and ulnar styloid process, relative to the initial position is calculated to determine the shoulder axial rotation. These angles allow to calculate the coupling angles.

2.5 Coupling angle description

The coupling angles named CA in Figure 1 highlights the coordination between the elbow and shoulder joints. Three coupling angles are defined for the elbow and shoulder:

- CA-Sag : Flexion/extension (sagittal plane)
- CA-Fron: Adduction/abduction (frontal plane)
- CA-Hum: Medial/lateral rotation around the humerus axis.

Based on the modified vector coding analysis of (Needham et al., 2015), CA are divided into bins of 45° corresponding to a specific coordination for each shoulder / elbow angles. Each bin, represented by the coupling angle between two dotted lines in Figure 1, describes simultaneous elbow and shoulder movements. For example, the bin 'In-Phase (Elbow Ext & Shoulder Flx/Abd/Med Rot)' indicates that the elbow is extending while the shoulder is either flexing (if CAS passes through), abducting (if CAF passes through), or medially rotating (if CAH passes through). The coupling angles were average among all participants and across the four repetitions. The mean curve is plotted with the standard deviation against the normalized ascending time (until hand take off).

3. Results and discussion

Figure 1 displays the coordination of the elbow and shoulder. Looking at the three curves together, we can see that the majority of the movement takes place with simultaneous (in-phase) movement of the shoulder and

elbow. Similarly, the start of the movement is made solely with elbow flexion. The first change in coordination occurs at 70%, when Ca-Fron changes to elbow flexion only. At around 85%, CA-Fron switches to anti-phase with elbow flexion and shoulder abduction. CA-Sag completes the movement from 90% to 100% with elbow flexion only.

While the elbow flexes throughout the entire ascent phase, the shoulder modifies its coordination in the different planes during the movement.

The switch from shoulder adduction to abduction reflects a strategy change for reaching higher. To maintain upward movement, climbers must use abduction, which may seem counterintuitive since this movement is away from the target. This strategy makes sense due to the continuous shoulder medial rotation, positioning the climber favorably for abduction to continue the ascent.

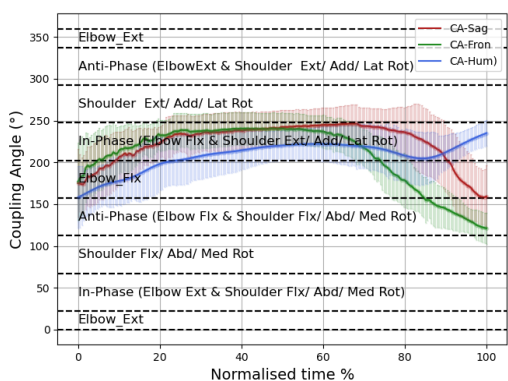


Figure 1 - Mean coupling angles on the sagittal (CAS), frontal (CAF) and around the humeral axis (CAH)

4. Conclusions

The decomposition of shoulder and elbow angles, explained thanks vector coding approach clearly demonstrates a specific shoulder and elbow joints coordination during the arm jump test. Almost 80% of the motion is performed with in-phase coordination, while a specific coordination is only observed at the onset and at the end of the test. At the onset, the elbow is the prime mover for the movement, while at the end of the movement, a specific shoulder coordination appears. It is characterized by a joint involvement depending on the plane with a change to an in-phase coordination to an anti-phase coordination in the frontal plane.

In future work, vector coding could be combined with inverse dynamics to have a better understanding of the motor coordination strategies related to muscle involvement during the arm-jump.

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Conflict of Interest Statement

None

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