ROLE OF LOWER AND UPPER LIMBS IN DYNO MANEUVER

Legreneur, P.[(1)], Thevenet, F-R.[(1)] and Bels, V.[(2,3)]

[(1)] Laboratoire Interdisciplinaire de la Biologie de la Motricité, University of Lyon, Villeurbanne, France. pierre.legreneur@univ-lyon1.fr

[(2)] Institut de Systématique, Evolution, Biodiversité, Muséum national d'Histoire naturelle, Paris, France. Vincent.bels@mnhn.fr

[(3)] Laboratory of Histology, University of Mons, Mons, Belgium.

Abstract

The main purpose of this study was to characterize the inter-articular coordination in rock climbing dyno. Indeed, this dynamic movement implies as well the lower limbs as the upper limbs. Aimed to evaluate the respective contributions of these limbs, this locomotion was compared to movements implying only the lower limbs (Squat Jump, SJ) or the upper limbs (Arm Jump, AJ). Nine high-level rock climbers were tested and filmed in the sagittal plane. The kinematics data showed that the joint coordinations in dyno are similar with the ones of the SJ for the lower limbs. However, differences were observed concerning the upper limb in AJ. It should be hypothesized that the lower limbs created most part of the body power. The upper limb, and particularly the elbow and the wrist, should have a postural function by controlling the distance between the body mass centre and the wall. However, the shoulder would participate to the impulsion too.

Keywords: Squat Jump, Arm jump, Interarticular coordinations

Résumé

L'objectif de cette étude a été de caractériser les coordinations inter-articulaires au cours d'un jeté en escalade. En effet, ce mouvement dynamique implique aussi bien les membres inférieurs que les membres supérieurs. Pour évaluer les contributions respectives de ces membres, le jeté a été comparé à des mouvements impliquant uniquement les membres inférieurs (Squat Jump, SJ) ou les membres supérieurs (Arm Jump, AJ). Neuf grimpeurs de haut niveau ont été testés et filmés selon le plan sagittal. Les données cinématiques ont montré que les coordinations inter-articulaires en jeté sont similaires à celles en SJ pour les membres inférieurs. Cependant, des différences ont été observées au niveau du membre supérieur en AJ. Il peut donc être supposé que les membres inférieurs ont pour fonction essentielle de créer de la puissance. Le membre supérieur, et en particulier le coude et le poignet, aurait une fonction posturale pour contrôler la distance entre le centre de gravité du corps et le mur. Les épaules participeraient également à la propulsion.

Mots clés : Squat Jump, Arm jump, Coordinations interarticulaires

Introduction

In sports, athletes are often required to achieve explosive movements, *i.e.* movements that are designed to produce a force at the interface between the periphery of the system and the environment in a very short time. Thus, during a vertical jump which duration is about 350 ms, the subject's performance is directly correlated with his ability to transmit a maximal total energy to the ground via his most distal segments, the feet.

In climbing, the dyno could be considered as an explosive movement. This movement makes it possible, following an impulse, to reach holds that are too far away to be reached in static mode. Unlike vertical jump, the dyno is a quadrupedic movement that involves the upper limbs and the lower limbs. However, there is no data in the litterature on interarticular coordinations required to transmit maximum power to the environment to reach a maximum height.

Thus, the aim of this study was to characterize the functions of the climber's upper and lower limbs in dyno maneuver.

Experimental procedure

Nine high-level male climbers (age: 22.8 ± 4.08 years; height: 176.55 ± 3.68 cm; mass: 65.22 ± 6,14 kg) volunteered for this study. They performed three different tests: a Squat Jump (SJ) on a force platform, an explosive pull up (Arm Jump - AJ) on a campus board, and a dyno on a climbing wall inclined at 35° with the vertical (Figure 1).

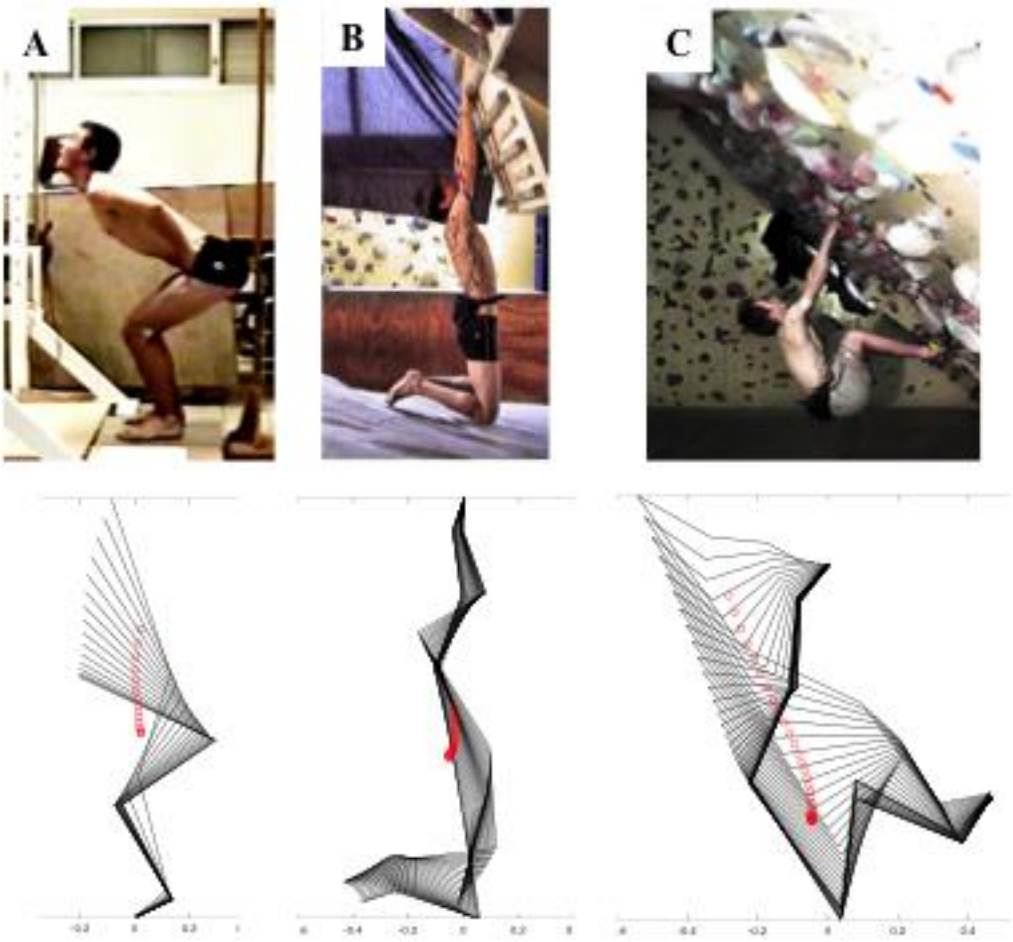

Figure 1. The 3 tests performed in this study: (A) Squat Jump; (B) Arm Jump; (C) Dyno. Below, stick digrams of the movements.

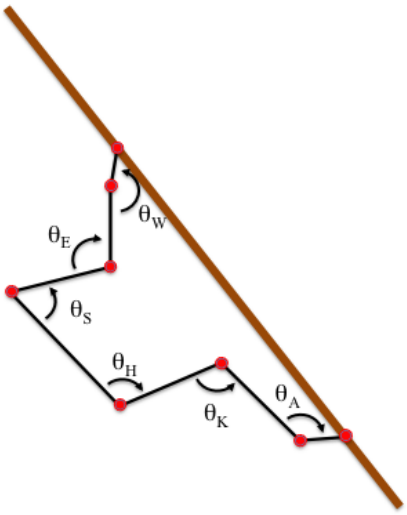

Figure 2. Joint angles. θ_W: wrist ; θ_E: elbow ; θ_S: shoulder ; θ_H: hip ; θ_K: knee ; θ_A: ankle.

Climbers were filmed in the sagittal plane at a frequency of 50 fps. These films were analyzed frame-by-frame to identify previously defined skeletal landmarks, i.e. the fifth metatarsophalangeal joint, ankle, knee, hip, and shoulder for SJ, AJ and dyno. For AJ and dyno we also digitalized the elbow, the wrist and the extremity of the fingers. Raw kinematic data were fitted using polynomial nonlinear filter (order 6).

In combination with anthropometric data from Winter (1990), the landmark coordinates were used to determine the position of each segment mass center, as well as the position of the body mass center (BMC). Interarticular coordinations were evaluated through the sequential order and timing of joint extensions. For this purpose, according to Haguenauer *et al.* (2006), the onset of each joint extension (Figure 3) was defined when its position was 5% higher than its angular position at the start of its extension phase.

All numerical calculations were performed using GNU Octave 4.2.2 software (Eaton *et al*., 2016).

Results & Discussion

The mean durations of the impulse phases for the three tests are significantly different (Figure 3 - Left). BJ is significantly longer than that of the SJ and the dyno. The dyno is significantly longer than that of SJ. So, the use of the upper limb significantly increases the impulse duration, but also increases the BMC velocity at take-off in dyno. It is possible to evaluate this increase of 40%.

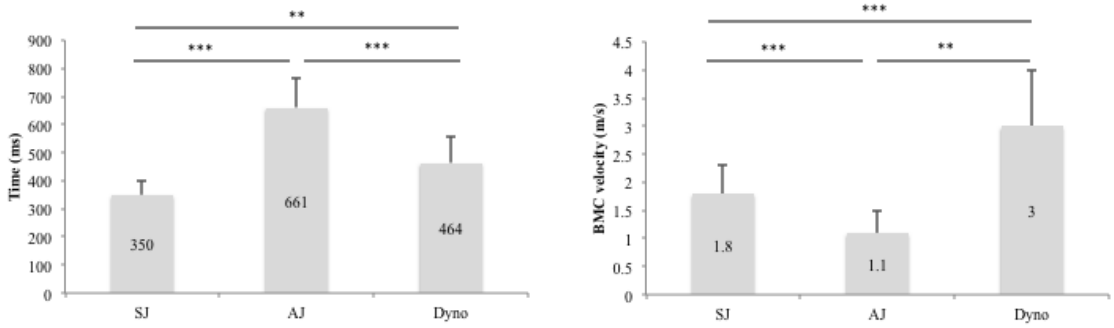

Figure 3. Left: Duration of impulsion phases for squat jump (SJ), arm jump (AJ) and dyno. Right: Body mass centre (BMC) velocity at take-off. **: $p < 0.01$; ***: $p < 0.001$.

In SJ, coordinations are those conventionally observed in the literature (Legreneur et al., 2013) (Figure 4 – Squat Jump), namely a proximo to distal extension of the lower limb joints, *i.e.* the extension of the hip precedes that of the knee which precedes that of the ankle. This coordination allows muscular power transfer from the trunk to the ground (Jacobs and Ingen Shenau, 1992). In AJ (Figure 4 – Arm Jump), The elbow and the shoulder displaced through a similar flexion pattern, with no displacement of the wrist. Thus, the power transfer is very inefficient, which explains the poor performance on this test.

In dyno (Figure 4 – Dyno), the wrist hardly moves and the elbow makes a flexion followed by extension. So it seems that only the shoulder participates in creating power. With regard to the lower limbs, there is a proximo to

distal coordination between the hip and the ankle. The knee also participates in the movement, but to a lesser extent.

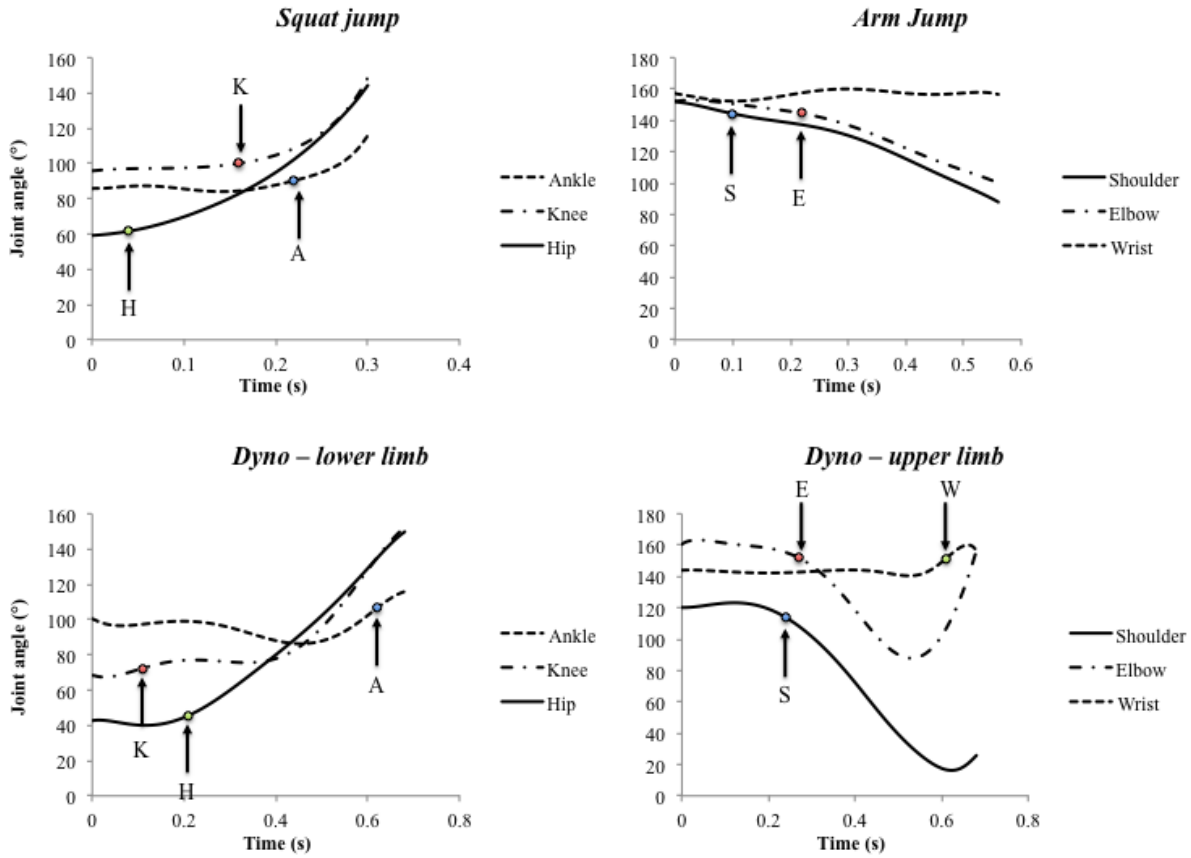

Figure 4. Coordinations in squat jump, arm jump and dyno. Arrows indicate the onset of joint extensions.

In conclusion, interarticular coordinations observed in dyno are similar to those in SJ for the lower limb. On the other hand, notable differences exist with the BJ for the upper limb, as only the shoulder seems to be propulsive (about 40% of the performance). Dyno presents therefore specific coordinations where the lower limb is the main source of power creation and the upper limb has to control the trajectory of the climber's BMC close to the support.

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