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Kinematic and kinetic comparisons of Jump pull ups used in rock-climbing evaluations

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1. Introduction

Arm power estimation tests are a gold standard to access the climber strength (MCT Details | ircra). They are performed with variation normal pull-up (PU), one hand slap test and arm jump test using both hands (Laffaye et al. 2014) to reach as high as possible (Draper et al. 2011). Rock climbing is a sport involving vertical quadruped motricity with static and dynamic movements. More recently the bouldering, route and speed climbing are more and more dynamically oriented. Speed climbing is pushing the limit in term of speed, force and coordination. The countermovement (CM) and concentric (Con) jump pull-up (JPU) could represent two different types of muscle contraction that could be directly applicable in rock climbing. This abstract aims to compare the two different forms of jump pull-up with kinematic and kinetic approaches.

2. Methods

2.1. Participants

Seventeen skilled climbers over 7c French route grade performed 4 jump pull-ups (JPU) in two different modalities: concentric (Con) JPU and countermovement (CM) JPU with stretch shortening cycle.

2.2. Protocol

Climbers were asked to jump in order to reach as high as possible with both hands simultaneously. In both modalities, each climber was asked to stabilize before starting the movement, with engaged shoulder and slightly bent arm (around 120°) for the Con JPU and at first 90° elbow inclination, before going down to 120° and up in an explosive way. Natural velocity was required

2.3. Material & data analysis

Each participant was equipped with an adapted Qualisys markers set to measure upper-limbs and body displacement. The jump height was measured using Qualisys marker at the hand. Each articular angle was measured in the upper-limb segments plane for shoulder θ_e , elbow θ_c and wrist θ_p joints as presented in Figure 1. These were obtained from marker positions and were derived (finite centered differences) to get corresponding angular velocity. The maximal velocity apparition time of each joint was estimated

and then normalized with respect to the ascending pull-up time. Two three-axis force sensors (225 Hz) were used to measure each hand reaction force during the JPU (Figure 1). Each force component was normalized to body weight. Both movement and force measured data were filtered with a fourth order low pass Butterworth filter with a cut off frequency of 10 Hz. For the height and the forces, a linear mixed model was used to compare modalities to account for inter-individual variability, followed by a comparison test between the 2 modalities. For peak joint velocities, a beta regression of y-value]0;1[was used to account for interindividual variability, followed by a comparison test.

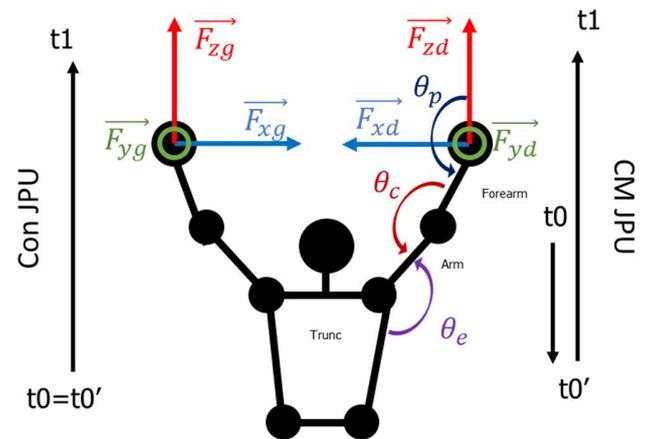


Figure 1 Schematic representation of the upper body with forces, angles of interest and vector of the CM and Con JPU (t_0 = start of the movement, t_0' = ascending phase, t_1 = take-off phase)

3. Results and discussion

3.1. Jump height

There is a significant difference between the measured mean jump height between the CM and Con JPU conditions, respectively 604.0 ± 24.8 mm and 584.9 ± 24.4 mm, ($Z = -3.36$; $p < 0.001$, $R^2 = 0.94$). The height estimated in the countermovement condition is 19 mm higher than the one estimated in concentric. The CM JPU is providing better result, certainly due the uptake of the slack muscle length (Van Hooren and Bosch 2016).

3.2. Angular velocity peak

Figure 2 displays a typical angular velocity-time evolution for the shoulder, elbow and wrist joints in the two studied modalities. Excluding the CM phase, angular velocities evolve in a similar way for both JPU. All joints are flexing during the whole movement with negative angular velocities in sagittal plane, excepted at the end of the pull-up where the shoulder and the wrist joints switch to extension in the frontal plane. At the moment of takeoff, shoulder joint exhibits especially height extension velocity in comparison with elbow and wrist joints. There is then a composition of the angular closure of the elbow and an

angular opening of the shoulder that allows the upward movement to be prolonged. Time delay between the maximal 3 joints velocities does not depend on the modality ($\chi^2(2) = 2.86; p=0.239$). The maximal angular velocity at shoulder joint appears significantly earlier than at the elbow ($Z=-14.35; p<0.0001$) and the wrist ($Z=12.82; p<0.0001$). On the other hand, no significant time delay is obtained between the maximal angular velocity at wrist and elbow joints ($Z=-1.9; p>0.136$). The shoulder seems to act mostly in the first part of the pull-up, while the elbow has a higher angular velocity near the end of the pull-up. Joint motion pattern exhibit a proximal-to-distal sequence for the first two joints as it has been generally observed in upper-limb throwing (Putnam 1993) or vertical jumping (Bobbert and van Ingen Schenau 1988). However, no significant trend can be established for the wrist. One explanation could be the lack of force production around this joint for a large angle amplitude.

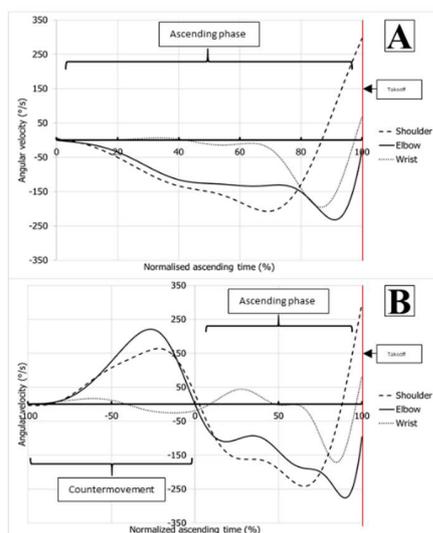


Figure 2 Typical example of angular velocity-time curves in Con JPU **A** and in CM JPU **B**

3.3. Forces at the hands

The Table 1 shows the maximal values reached by the sum of each axial absolute force during the concentric ascending phase, related to the participant's weight. The differences in maximal forces measured, between the CM and Con JPU are not significant ($F_x: p=0.4; F_y: p=0.07; F_z: p=0.84$), although we can identify a tendency for antero-posterior force to be higher during CM JPU than Con JPU. The increased performance of the CM JPU does not come with higher maximal forces. In addition, the maximal measured efforts in frontal and sagittal planes are not neglectable (from 22% to 40% of the weight). This suggests that these efforts should be taken into account, even if they do not directly contribute to performance.

Table 1 Maximal absolute forces at the hands during the JPU movement in both modalities

Modality	F_x	F_y	F_z
CM JPU	22.5%	40.0%	154.6%
Con JPU	21.7%	37.0%	152.4%

4. Conclusions

The CM JPU performance has a significantly superior height compared to the Con JPU.

Both JPU are sequenced in a proximal-to-distal pattern for shoulder and elbow joints and generate a maximal hand reaction force of similar amplitude. CM JPU does not imply producing greater efforts in the ascent phase to provide higher jump.

This study allows us to highlight the non-vertical stabilization forces present during the pull-up movement which represent a significant part of the effort produced.

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