INTERPRETATION OF HIP MECHANICAL ENERGY IN OFFICIAL SPEED CLIMBING ROUTE

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Abstract

Speed climbing is for sport climbing what sprinting is to athletics. It is practiced on a standardized and internationally accredited wall. 9 locomotor phases are identified, *i*.e. (1) start, (2) turning, (3) first acceleration, (4) first dyno, (5) second acceleration, (6) second dyno, (7) the last three holds and (8) the final. Here, we characterized climbing performance of a high level athlete with regard to the mechanical energy variations of the hip during ascent. Morever, we interpreted these variations according to the different locomotor phases. Experimental data showed that the speed of the climber decreases very strongly, or became null on three phases of the track: the turning, the first dyno and the second dyno. Thus, the energy produced after each acceleration phase, i.e. start, 1st acceleration and 2nd acceleration, is dispersed. In conclusion, these results show that the potential for improving performance is important by working specifically on the conservation of the kinetic energy of the climber on the various phases of the track.

Keywords: Speed climbing; Entropy; Potential energy; Kinetic energy; Performance optimisation

Résumé

L'escalade de vitesse est à l'escalade sportive ce que le sprint est à l'athlétisme. Elle est pratiquée sur un mur normalisé et internationalement homologué. 9 phases locomotrices sont identifiées, à savoir (1) le départ, (2) le virage, (3) la première accélération, (4) le premier jeté, (5) la seconde accélération, (6) le deuxième jeté, (7) les trois dernières prises et (8) le final. Nous avons caractérisé la performance d'un athlète de haut niveau au regard des variations d'énergie mécanique de la hanche pendant la montée. De plus, nous avons interprété ces variations en fonction des différentes phases locomotrices. Les données expérimentales ont montré que la vitesse du grimpeur diminue très fortement, ou devient nulle sur trois phases de la voie : le virage, le premier jeté et le deuxième jeté. Ainsi, l'énergie produite après chaque phase d'accélération, à savoir le démarrage, la première accélération et la seconde accélération, est dispersée. En conclusion, ces résultats montrent que le potentiel d'amélioration de la performance est important en travaillant spécifiquement sur la conservation de l'énergie cinétique du grimpeur sur les différentes phases de la voie.

Mots clés : Escalade de vitesse; Entropie; Energie potentielle; Energie cinétique; Optimisation de la performance

Introduction

Speed climbing is for sport climbing what sprinting is to athletics. It is practiced on a standardized and internationally accredited wall (Figure 1). This standardization has allowed the validation of records. The wall is 15.5 m. The inclination is 5° and each lane is at least 3 meters wide. The wall consists of 2 lanes as the competitions take place in the form of duels. There are only two types of holds: 20 for the hands, and 11 for the feet. The difficulty of the route is estimated at 6b+ (5.11a). For timing, the start is given by a sound signal. When the climber takes off from the ground, a system connected to an electronic mat triggers the stopwatch. It stops once the climber presses a button or pad at the top of the wall.

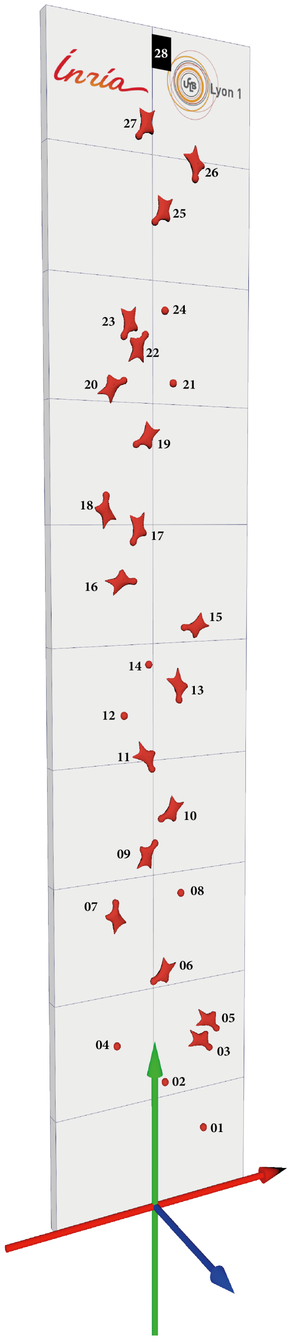

Figure 1. Official speed climbing route (15.5 m wall).

The male word record is 5.48 s (Reza Alipourshenazandifar, Iran, 2017). The female word record is 7.38 s (Juliia Kaplina, Russia, 2017). 9 locomotor phases are identified by the French coaches (personal communication, Sylvain Chapelle, 2017) during climbing with reference to the numbering of the holds shown in Figure 1, *i*.e. (1) start (holds 1 to 6), (2) turn (holds 6 to 7), (3) first acceleration (holds 7 to 13), (4) first dyno (holds 13 to 16), (5) second acceleration (holds 16 to 23), (6) second dyno (holds 23 to 25), (7) the last three holds (holds 25 to 27) and (8) the final (holds 27 to 28).

On our knowledge, there is currently no scientific study on speed climbers' performance. The aim of this study is therefore to characterize this performance with regard to mechanical energy variations of the hip during the ascent and to interpret them according to the different locomotor phases of climbing.

Experimental procedure

One female climber (Anouck Jaubert, France, 2017 IFSC Speed Season Champion, mass = 55 kg, height = 1.66 m) performed 8 maximal speed ascents on the official route. Mean ascent time was 8.43 ± 1.03 s. We selected the best trial (ascent time = 7.96 s) for further analysis. Climber was simultaneously filmed in the sagittal and dorsal planes at a frequency of 30 Hz with two drones (DJI Mavic Pro) which vertically followed the climber (Figure 2). For this paper, we used only dorsal view. A landmark fixed onto the harness was digitalized frame by frame in local reference frames depending on the position of the climber in the route. The coordinates were then calculated in a terrestrial reference system. All numeric calculations have been performed using GNU Octave 4.2.2 software (Eaton *et al.*, 2016). Raw kinematic data were fitted using a Savitzky-Golay filter.

The geometric entropy (*GE*) was computed by taking the natural logarithm of two times the length of the pattern travelled by the landmark (*LM*) divided by the perimeter of the convex hull (*CH*) (Figure 2) around that path (Cordier et *al.*, 1994). *GE* was computed on the dorsal planes as

$$GE = log\left(\frac{2 \times LM}{CH}\right)$$

GE is zero when the trajectory is strictly linear. It increases when the desorder of the trajectory increases.
Total energy is calculated as the sum of potential energy (PE) and kinetic energy (KE):

$$PE = mgh \text{ and } KE = \frac{1}{2} mv^2$$

where m is the climber's mass (kg), $g = 9.81\ ms^{-2}$, h is the height of the hip (m) and v its linear velocity (ms^{-1}).

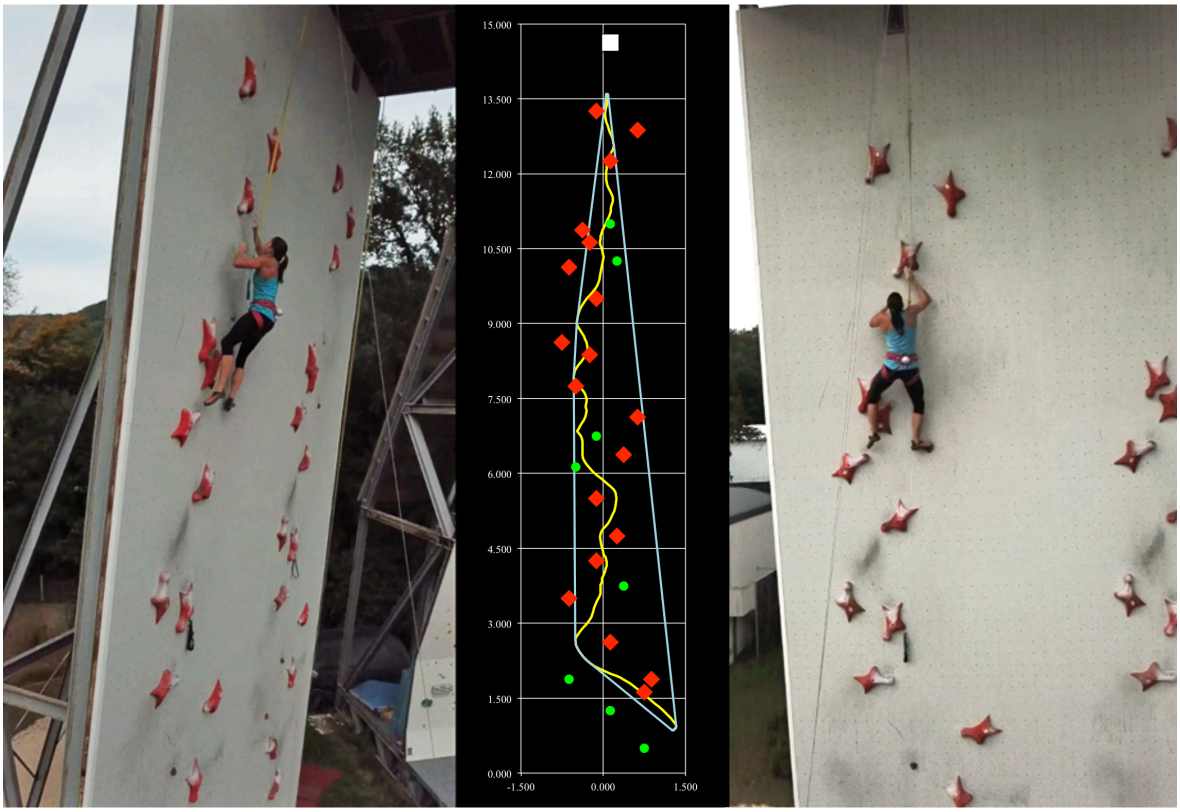

Figure 2. Video acquisition of the climber with 2 coordinated flying drones (Left: sagittal view; Right: dorsal view). A landmark fixed onto the harness materializes the hip. Centre: trajectory of the hip in the dorsal plane (yellow line), convex hull of the trajectory (blue line). Feet and hands' holds are respectively symbolised with green dots and red diamonds.

Results and discussion

The overall trajectory of the climber is constrained by the topology of the route. The start of the route is at an angle of 45° to the left to reach a height of 3 m. After a turn, the climber climbs vertically to the top. At the start, the left foot is on a ground pad and the right foot on the first foot hold (#1). For the hands, two positions are possible depending on the climber's height, *i.e.* both hands on hold #3 or the left hand on hold #3 and the right one on hold #5. Notice that the 9th hand hold (#15) at the middle of the first dyno is not used at high level. This topology means that the convex hull of the climber's trajectory has a triangular shape, with the base at the beginning of the route and the tip at the top. For this trial, the geometric entropy was 0.103.
From a theoretical point of view, the climber's movement is optimal if his total energy increases according to a constant and maximum slope as a function of time. For that, PE must increase without presenting any plateau that would indicate a stop of the vertical displacement of the climber. Concerning KE, it should be constant, or increase to top of the route. However, experimental data do not account for these theoretical data. Indeed, the speed of the climber decreases very strongly, or became null on three phases of the track: the turning, the first dyno and the second dyno. These decreases lead to loss of time, and in particular in dyno. Thus, the energy

produced after each acceleration phase, i.e. start, 1st acceleration and 2nd acceleration, is dispersed. In addition, after each slowdown, the climber must produce high levels of force to accelerate again.

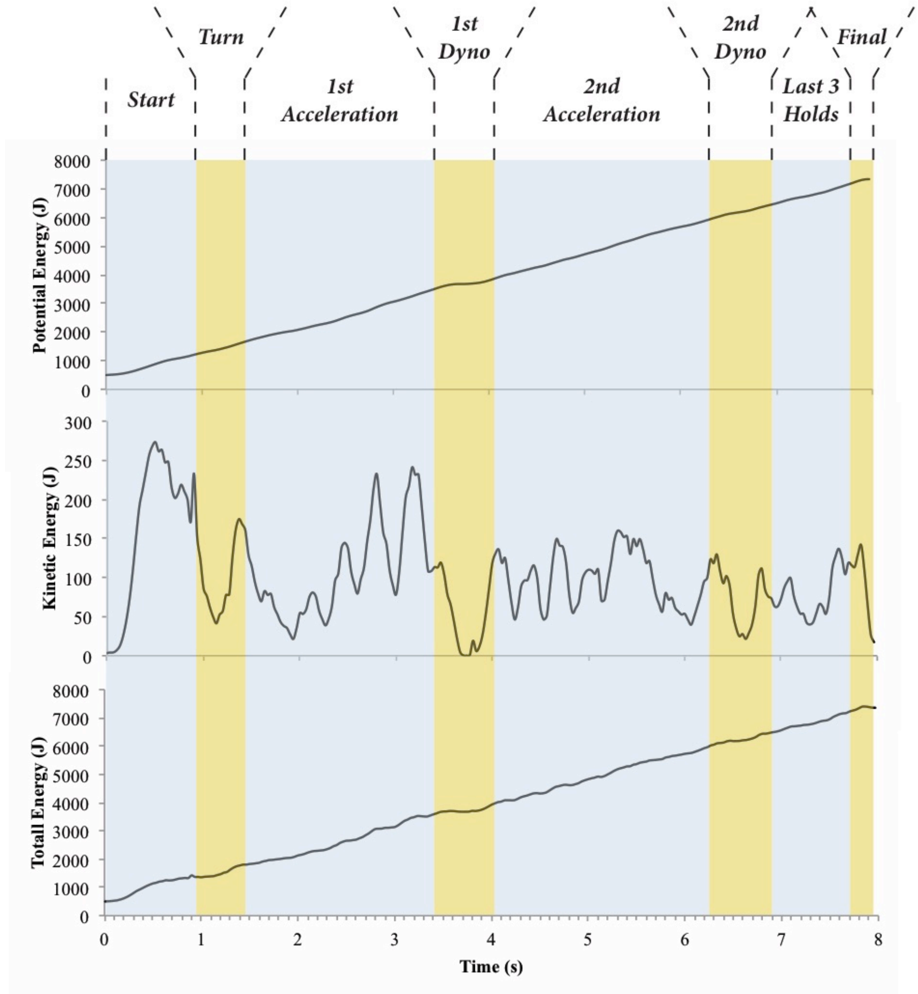

Figure 3. Energy patterns of the climber in speed climbing *vs.* time. Top: potential energy (PE); Middle: kinetic energy (KE); Below: total energy (PE + KE). The 8 phases of the route are indicated above.

In conclusion, these results show that the potential for improving performance is important by working specifically on the conservation of the kinetic energy of the climber on the various phases of the track.

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