BIOMECHANICS OF THE SINGLE-HANDED DYNAMIC MOVES ON CAMPUS BOARD AND EFFECT OF RUNG DISTANCE

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The purpose of this study was to gain an insight into the kinematics and kinetics of the single-handed dynamic moves on campus board and investigate the effects of increased rung distance on biomechanical parameters. Eight climbers, six males and two females, performed various single-handed dynamic moves on an instrumented campus board. Kinematic and kinetic data were collected during each jumping move. The results showed that duration of acceleration and flight phases increased and duration of control phase decreased with increasing target distance. The reaction force on the starting rung in acceleration phase and the reaction force on target rung were found increasing with increasing target distance.

KEY WORDS: rock climbing, dyno, kinematic, reaction force.

INTRODUCTION: In the last two decades a growing interest has been observed for sport climbing both as a recreational activity and a competitive event. This interest and improved training methods induced an enormous progress in climbing standards. Today’s hardest routes are mostly on overhanging walls and/or they have really small holds in which the majority of body weight is carried by relatively small muscle groups of the forearm. Besides, dynamic moves which require timing, coordination and high finger contact strength which is the ability to apply high force rapidly on a hold at the initial contact have been widely seen in both extreme bouldering routes and climbing competitions. Thus, having a high finger contact strength and upper body power are the crucial parameters for advanced climbers. One of the most common method to improve explosive upper body power and finger contact strength is the campus board training exercises (Hörst, 2002; Hague & Hunter, 2006). Even though these exercises frequently practised by climbers and known as gold standard for upper body power training, they also have a high risk of injury when performed incorrectly or by young climbers who are under the age of eighteen. Surprisingly, there are very limited studies on dynamic moves in rock climbing (Köstermeyer & Tusker, 1996; Fuss & Niegl, 2010; Phillips & Jensen, 2016) and no study has been done on dynamic campus board exercises practised without feet. The purpose of this study was therefore to gain an insight into the kinematics and kinetics of the single-handed dynamic moves on campus board and investigate the effects of increased rung distance on biomechanical parameters.

METHODS: Eight climbers, six males and two females, (age 28.1 ± 6.7 years, height 175.8 ± 9.2 cm, body mass 70.5 ± 11.7 kg) participated in this study. All of them were regularly climbing inside/outside and free from any finger, elbow or shoulder injury at the time of testing. They had a minimum 5 years of climbing experience (12.7 ± 4.3 years) and were familiar with campus board training and dynamic movements.

Participants performed a standard warm-up and familiarization session which include assisted hangs and laddering moves on campus board rungs after their own personal warm-up session. Afterwards a short rest period was given and the test session was started. Participants hanged on the starting campus rung with two hands and pulled on the starting rung with both hands. Then they released one hand to catch the target rung similar to regular laddering exercises on campus board.

A specially designed 15 degrees overhang campus board frame was constructed and instrumented with a force plate (Kistler 9281C, Kistler Instrument AG, Winterthur, Switzerland). Seven wooden rungs with 35 mm depth (Beastmaker, Sheffield, UK) were fixed on the campus board frame with 22 cm spacing. The campus board moves were named with rung numbers according to the distance between starting (always #1) and target rung as usual in campus board training terminology: 1-2 = 22 cm, 1-3= 44 cm etc. Participants performed various dynamic moves from 1-2 to their maximal level. Each particular dynamic move was done eight times: two for left/right hand, two for measuring the contact forces at starting and target rungs and two trials for each case. Conditions were randomized and divided into four blocks which includes eight trials. A one minute rest was given after each campus move and a four minutes rest period was given in between each blocks.

Prior to data collection 53 passive reflective markers and 8 clusters with three markers were attached to the selected body landmarks and segments respectively. Campus board moves were captured with a 12-cameras motion analysis system at 240 Hz and synchronised force data was recorded at 960 Hz (Vicon Nexus 2.5, Vicon Motion Systems, Oxford, UK). 3D Motion and force data were exported to Visual 3D software (V6, C-Motion, Rockville, USA) and joint/segment kinematic/kinetic calculations were performed. Displacement and force data were filtered with Butterworth zero lag low pass filter at 6 Hz and 15 Hz respectively. Campus board dynamic moves were time normalised between the instances of start (0%) and end of motion (100%). Key events (start, take-off, catch and end) were defined and the jumping move divided into three phases: acceleration/pull, single-hand support/flight and control phases.

Descriptive analysis were used to present overall look to the biomechanical parameters in different campus board moves. All descriptive calculations and analysis were performed in MATLAB for windows (The Mathworks Inc., MA, USA).

RESULTS: During campus ladder moves, climbers started to accelerate their body by applying forces on the starting rung with two hands. Then they released one of the hand (move hand) at take-off point and continue to apply force with the fixed hand during the flight/single arm support phase and also after catch to control the body swing. Acceleration phase of a campus move started with a movement on upward (-y) and outward (+z) directions. Afterwards, just before the take-off instant, climbers pulled themselves to the campus board frame and the flight phase started on upward and inward (-z) directions.

Acceleration phase started with high flexion of the lower body and an extension at the knee joint followed. This extension was found more extreme at the reverse side's knee (right knee for a left hand move) for extreme campus rung moves to balance the arm move and to be able to grab the target rung. A continuous flexion at trunk in which started in acceleration phase and continued in one arm support phase was also noticed. Just before the take-off and the first part of the one arm support phase trunk was laterally flexed and rotated to the fixed hand side.

Table 1 presents the duration of the key phases of tested dynamic moves on campus board. Duration of acceleration phase was found longer at 1-3, 1-4 and 1-5 than 1-2 move. Similarly, flight time increased with increasing target distance from 1-2 to 1-4 and 1-5 moves. On the contrary, control phase duration after catch get shorter with increasing target distance. This result revealed that climbers had less time to stop the downwards motion of their body after grabbing the target rung for the extreme distance campus board jumps.

Table 1
Duration of key phases for left and right hand campus jumps (mean ± SD in seconds)

	Acceleration Phase (s)		Flight Phase (s) (One-arm pull)		Control Phase (s)	
	Left	Right	Left	Right	Left	Right
1-2	0.39 ± 0.11	0.41 ± 0.10	0.22 ± 0.04	0.21 ± 0.02	0.23 ± 0.12	0.25 ± 0.14
1-3	0.52 ± 0.11	0.55 ± 0.10	0.25 ± 0.03	0.24 ± 0.03	0.19 ± 0.06	0.23 ± 0.09
1-4	0.56 ± 0.08	0.59 ± 0.10	0.27 ± 0.02	0.26 ± 0.02	0.14 ± 0.05	0.19 ± 0.10
1-5	0.52 ± 0.07	0.56 ± 0.04	0.30 ± 0.03	0.26 ± 0.03	0.09 ± 0.02	0.09 ± 0.04

Vertical take-off velocities ranged between -0.63 ± 0.13 and -1.27 ± 0.12 m/s and increased with the rung distance for both left and right hand jumps. Position of the distal end of the middle finger and the target rung were examined and a very small amount of overshoot (0.02 ± 0.01 m) was noticed at all campus moves. Participants jumped slightly above the target rung. But, no relationship between overshoot and target rung distance was found. In addition, it was noticed that participants grab the target rung with a positive centre of gravity vertical velocity. This result revealed that climbers grabbed the target rung when their bodies were moving downward.

The elbow angle of moving arm at take-off was found larger at short distance moves like 1-2, 1-3 and smaller (more flexed position) at extreme moves like 1-4, 1-5. Conversely, elbow angle at catch instant increased with rung distance and reached almost fully extended position at the maximal campus board moves for each subject.

The reaction force results on the starting rung revealed that normalized maximal vertical force ranged from -1.28 ± 0.16 to -1.71 ± 0.17 times body weight (BW) and get higher values as the target rung distance increased in the acceleration phase. It was observed that climbers first pushed themselves out of campus board frame then pulled again before the take off. The A/P reaction forces were measured very small and slightly changed for different campus moves. Pushing A/P force was found increasing till 1-4 moves but a continuous increase was observed at the pulling A/P forces in relation with the increasing target distance (Figure 1a).

A considerable amount of vertical force was applied by the lower hand during the flight and control phases to support upward movement of body centre of gravity and also to stabilize body motion after catching the target rung. Mean vertical flight phase forces were found -0.56 ± 0.09 times BW and -0.57 ± 0.08 times BW for left and right hand moves respectively. Lower hand force slightly decreased with increasing target distance in the flight phase and this decrement was much more at the extreme 1-5 move. In the control phase similar vertical force intensities and changes were observed. Mean forces were found -0.57 ± 0.11 times BW and -0.57 ± 0.09 times BW for left and right hand moves respectively.

Normalized reaction forces at the target rung ranged from -0.57 ± 0.10 to -0.83 ± 0.12 times BW and from 0.02 ± 0.02 to 0.10 ± 0.04 times BW on vertical and A/P directions respectively. Reaction forces were increased in both vertical and A/P directions based on the increasing target rung distance (Figure 1b).

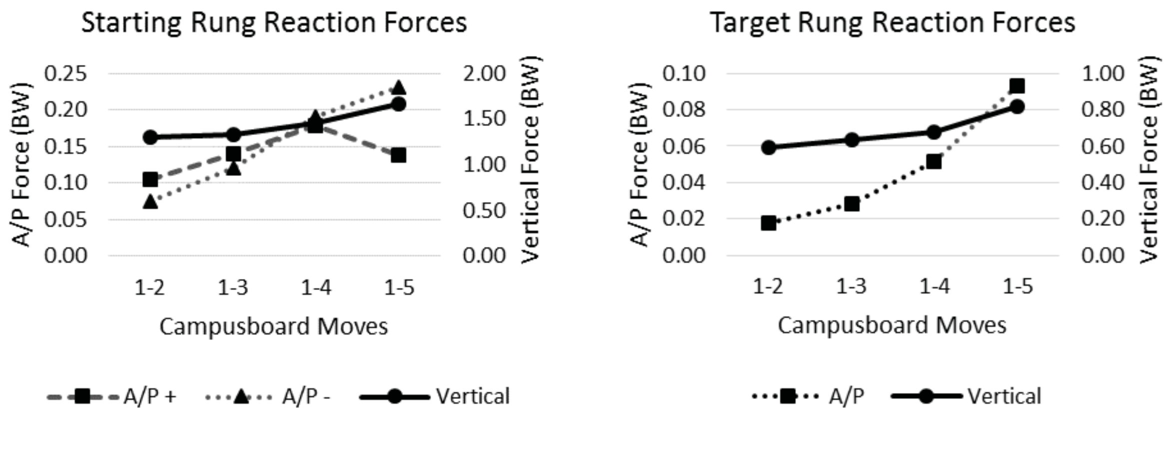

Figure 1: BW normalized peak reaction forces at lower rung in acceleration phase (a) and BW normalized peak reaction forces at target rung in control phase (b)

DISCUSSION AND CONCLUSION: The results of the study showed that control phase duration after catch gets shorter with increasing target distance, especially a very short time window was exist for the extreme maximal moves. So, climbers need to recruit their muscles very rapidly and apply high forces on the target rung to successfully grab it. In addition, the elbow angle was found getting more extended position to be able to reach and catch the target rung in maximal campus moves. In relation with shorter control phase duration, this more extended elbow position caused a very limited angular margin to stop the downward motion of the body before reaching the fully extended arm position which causes unwanted high impact forces on wrist, elbow and shoulder joints and increase the finger reaction forces in which is possibly resulted with an overuse, injury or failure of dynamic move. During campus board training, climbers need to be careful on their elbow angles at the catch instant and try to increase their take-off velocities instead of using more extended arm positions to reach and grab the target rung. It might be advisable to climbers who train on campus board to set a goal of having higher take-off velocity and catching a submaximal distance target rung with more flexed arm position instead of having an extreme move goal. In addition, it might also be advisable to add some extra weights to increase the force intensity and do campus board training with shorter rung distances.

In addition, the results indicated that continue to pulling and also pushing for the extreme campus moves with the lower hand as long as possible during flight phase was very important. The participants of the current study applied 0.57 BW on average in flight and control phases. It might be a crucial parameter in order to successfully reach the higher rung (or holds in routes) and also to reduce the impact forces at the target hold and injury risk for single-handed dynamic moves.

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