

BIOMECHANICAL ANALYSIS OF MIXED CLIMBING PERFORMANCE

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Abstract: Mixed climbing is a unique style of climbing that consists of ascending rock and ice features using ice climbing equipment. Despite the growing popularity of mixed climbing, there is a lack of knowledge regarding the relationship between climbers' biomechanics and performance. The purpose of this study was to conduct a biomechanical analysis of climbers during an international high-level mixed climbing competition. In total 24 climbers participated in this study (16 male, 8 female; age: 36 ± 6.2 years; weight: 69.1 ± 9.6 kg; height: 176.5 ± 8.8 cm). Video data was recorded during the mixed climbing competition and biomechanical analysis software was used to measure spatiotemporal (time climbing/resting, number of moves/rests) and kinematic variables (shoulder and elbow angles) throughout the competition route. Independent t-tests were used to examine differences between advanced (bottom 50% of competitors) and elite (top 50% of competitors) climbers, and a correlation matrix was assessed the strength of the relationship between the measured variables. We found that elite climbers moved significantly faster and used less moves than advanced climbers, and there was a high correlation between elbow and shoulder angles, indicating that climbers rely on more extended arm positions to decrease muscle fatigue.

Keywords: Rock climb; Ice climb; Kinematics; Motion analysis

ANALYSE BIOMÉCANIQUE DES PERFORMANCES D'ESCALADE MIXTE

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Abstract: L'escalade mixte est un style d'escalade unique qui consiste en une ascension de roches et de glaces à l'aide d'équipement d'escalade sur glace. Malgré la popularité croissante de l'escalade mixte, il existe un manque de connaissances concernant la relation entre la biomécanique et la performance des grimpeurs. Le but de cette étude était de réaliser une analyse biomécanique des grimpeurs lors d'une compétition internationale d'escalade mixte de haut niveau. Au total, 24 grimpeurs ont participé à cette étude (16 hommes, 8 femmes, âge: 36 + 6,2 ans, poids: 69,1 + 9,6 kg, taille: 176,5 + 8,8 cm). Des données vidéo ont été enregistrées lors de la compétition d'escalade mixte et un logiciel d'analyse biomécanique a été utilisé pour mesurer les variables spatiotemporelles (temps de montée / repos, nombre de mouvements / silences) et cinématiques (angles de l'épaule et du coude). Des tests t indépendants ont été utilisés pour examiner les différences entre les grimpeurs avancés (50% inférieurs des concurrents) et élites (50% supérieurs des concurrents), et une matrice de corrélation a été évaluée sur la force de la relation entre les variables mesurées. Nous avons constaté que les grimpeurs d'élite se déplaçaient beaucoup plus vite et utilisaient moins de mouvements que les grimpeurs avancés, et qu'il existait une forte corrélation entre les angles du coude et de l'épaule, indiquant que les grimpeurs se reposaient davantage.

Keywords: Escalade; Montée de glace; Cinématique; Analyse de mouvement

Introduction

Mixed climbing is a unique style of climbing that consists of ascending rock and ice features using ice climbing equipment. The sport of mixed climbing has seen considerable growth in recent years, as evidenced by the movement of the Union Internationale des Associations d' Alpinisme (UIAA) to have the sport of ice climbing included in the Winter Olympics.

There are several components of ice and rock climbing technique that contribute to a climber's mixed-climbing skill level. Seifert, Wattedled, L'Hermette & Herault (2011) found that expert ice climbers demonstrated higher variability in limb movement than novice climbers. Additionally, Seifert, et al. (2011) concluded elite level rock climbing movement patterns are characterized by smoothness and fluency in movement dynamics and hand-hold reaction forces. Further, studies have shown that elite and advanced climbers differ in terms of physical traits. Ozimek, Staszkiwicz, Rokowski & Stanula (2016) found that elite rock climbers demonstrated significantly greater finger strength and arm endurance, as well as significantly lower calf circumference than less skilled climbers. Additionally, Schreiber, Allenspach, Seifert & Schweizer (2015) observed that the pulleys in the fingers of rock climbers' hands were up to 82% thicker than those in the hands of non-climbers.

Two particularly important aspects of ice climbing are the strike motion of the ice axe and arm position (shoulder and elbow angles) during the swing. The strike motion of an ice climber's ice axe is a technical move that secures the climber to the ice and allows them to ascend the wall. Robert, Rouard & Seifert (2013) defined the two phases of the strike motion as: (1) the cocking phase, where the ice axe moves to its furthest posterior position, and (2) the striking phase, where the ice axe is swung anteriorly, coming into contact with the ice. Robert et al. (2013) concluded that elite ice climbers demonstrated significantly different axe swings than novice climbers.

Despite the growing popularity of mixed climbing, there is a lack of knowledge regarding the relationship between climbers' biomechanics and performance. The purpose of this study was to conduct a biomechanical analysis of climbers during an international high-level mixed climbing competition and to assess the relationship between these biomechanical variables and performance.

Methods

In total 24 climbers participated in this study (16 male, 8 female; age: 36 ± 6.2 years; weight: 69.1 ± 9.6 kg; height: 176.5 ± 8.8 cm). The Fort Lewis College Institutional Review Board approved the protocol for this study and all competitors provided their written informed consent. Subjects were categorized as advanced (bottom 50% of competitors) and elite (top 50% of competitors) climbers based on their finishing rank in the competition. The competition was scored based on how high participants ascended the wall in the allotted time (8 minutes). All participants attempted the same mixed climbing route, which consisted of a short ice section, followed by a rock face and ended on a man-made feature.



Figure 1. Lower portion of competition route showing the holds used for analysis

Two cameras [GoPro Hero 5 (Go Pro Inc., San Mateo, CA, USA) and Pentax K-3 IIS (Pentax, Tokyo, Japan)] recorded video footage of the participants from left and right vantage points of the competition route. Video data was analyzed with Kinovea video analysis software (version 0.8.15). Kinetic measures consisted of each participant's elbow angle (EA) and shoulder angle (SA), which were measured at 5 holds (Hold 1-5) that were used by all participants (Figure 1). EA and SA were measured at the point when the participants' ice tools were weight bearing on each hold. Spatiotemporal variables consisted of the time spent climbing/resting and the number of moves/rests.

Data was analyzed with a correlation matrix to examine the strength of the relationships between all measured kinematic and spatiotemporal variables, and independent t-tests to examine differences between advanced and elite climbers for each variable. Statistical analyses were conducted in Excel (Microsoft, Redmond, WA, USA). Statistical significance was defined as $p \leq 0.05$, which corresponded to a critical r-value of 0.404 for correlations.

Results

The correlation matrix showed several significant relationships between the measured variables. The arm angle related variables (SA and EA for Holds 1-5) had the following significant correlations: $r = 0.75$ between Hold 1 SA ($128.7^\circ \pm 18.7^\circ$) and Hold 1 EA ($159^\circ \pm 14^\circ$), $r = 0.54$ between Hold 2 SA ($137.6^\circ \pm 22.8^\circ$) and Hold 2 EA ($151.1^\circ \pm 16.5^\circ$), and $r = 0.61$ between Hold 4 SA ($139.3^\circ \pm 16.8^\circ$) and Hold 4 EA ($166.2^\circ \pm 12.1^\circ$). Figure 2 shows a representative example for the relationship between EA and SA for Hold 1.

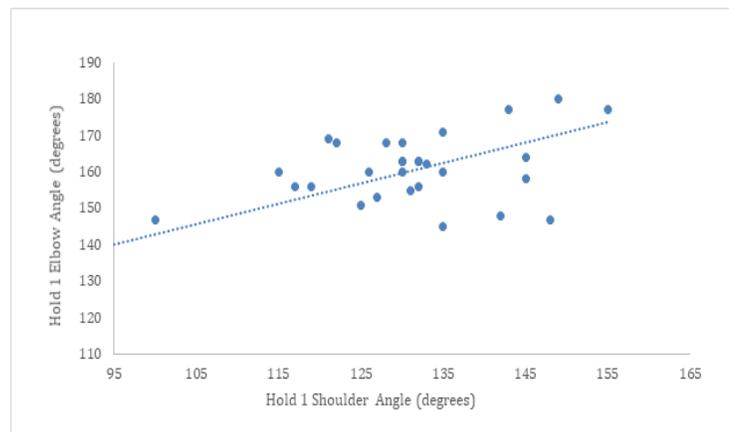


Figure 2. Relationship between Hold 1 EA and Hold 1 SA, $r = 0.75$

The results of the t-tests showed significant differences between elite and advanced climbers for Number of Moves On Route (28.8 ± 8.62 moves, $p = 0.0012$) and Time Between Clip 2 and Hold 5 (186.6 ± 67.1 s, $p = 0.00005$) (Figure 3). The remaining variables showed no significant differences between the two groups ($p > 0.05$).

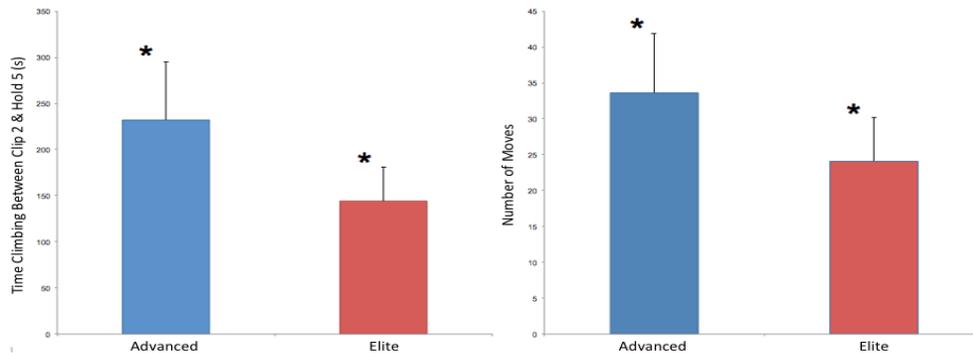


Figure 3. (Left) Comparison of the Time Between Predetermined Points for advanced vs. elite climbers. (Right) Comparison of the Number of Moves for advanced vs. elite climbers. A move was defined as the climber securely contacting the wall with the ice axe or hand. Significant differences are indicated by * ($p \leq 0.05$).

Discussion

The purpose of this study was to conduct a biomechanical analysis of climbers during an international high-level mixed climbing competition. We found significant differences between advanced and elite climbers in terms of time climbing and number of moves, as well as significant correlations between SA and EA for Holds 1-4; all other variables were not significant.

Our finding that elite mixed climbers ascend the route significantly more quickly than advanced climbers is in agreement with Seifert, Wattedled, L'Hermette, Bideault, Herault & Davids (2013). Additionally, Mermier et al. (2000) conducted a study in which elite and less elite rock climbers were assessed in terms of their ability to read a climbing route and adapt the necessary moves to finish the route. It was found that more elite climbers were able to read the route more efficiently and performed better on their first attempt. Thus, it is likely that the elite climbers observed in the present study read the route more readily, and hence were able to complete the climb more quickly and with fewer moves.

In conclusion, we found that elite mixed climbers climbed faster and with less moves than advanced climbers. These findings suggest that mixed climbers should focus on decreasing the number of moves used and increasing their speed on route in order to improve performance. We also found a strong correlation between EA and SA for Holds 1-4, which suggests that placing ice tools on holds with a straight arm (extended EA and SA) may decrease muscle fatigue by distributing bodyweight to the skeleton rather than relying on active upper-body musculature. Mixed climbers may potentially improve their performance by utilizing more extended arm angles while climbing to save energy.

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