RELIABILITY OF JOINT ANGLE MOVEMENTS DURING ROCK CLIMBING

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INTRODUCTION

The nature of rock climbing requires the individual to transport body mass vertically, with varying degrees of support, through a series of complex movements and body positions. Although more researchers have begun to study physiological responses (Watts, 2004); only Sibella et al. (2006) have reported kinematic data of actual climbing. Their study examined center of mass movement, but did not address joint angle changes, or whether these changes are consistent. Thus the purpose of the current study was to assess the reliability of joint angle movements during repeated trials of rock climbing.

METHODS AND PROCEDURES

Ten subjects (mean ± SD: age = 31.6±13.9 years; height = 177.5±8.6 cm; body mass = 73.8±10.7 kg) wore their own rock climbing shoes during testing. Each subject completed four trials of a climbing movement sequence on a vertical indoor wall (Figure 1). The specific movement sequence is known to climbers as a *high-step* Climbers performed two trials (T1, T2) randomized by conditions of foot placement (1) Inside edge = where the area on the inside of the shoe near the base of the great toe is used for contact and support; and (2) Toe-in = where the front part of the shoe at the toe is used for contact and support. Subjects self-selected the rate of movement and specific body positioning, other than the right foot, during each climbing trial. Subjects gave informed consent prior to participating in the study which had IRB approval.

Reflective markers placed on the subject's right ulnar head, lateral humeral epicondyle, acromion, greater trochanter, fibular head, lateral malleolus and atop the great toe were used to determine joint angles using Peak Motus 8.5. Data were acquired at 60 Hz and a 2nd order Butterworth filter with a cut off of 3-6 Hz was used to smooth the data (Winter, 2005).
Intraclass correlation (two way mixed analysis) and repeated measures ANOVA were used to estimate reliability and test differences among trials via SPSS 15.0. The parameters of interest were maximum (MAX), minimum (MIN), and average (AVE) joint angles for the elbow, shoulder, hip, knee, and ankle.

Figure 1. A subject performing the climbing movement.

RESULTS

Intraclass correlation coefficients (ICC) for the MAX, MIN, and AVE joint angles are displayed in Table 1. Significant differences ($p < 0.05$) were found between trials for MAX Ankle (108.3±5.7° vs. 110.1±6.3°), and MIN Ankle (90.9±5.9° vs. 92.7±5°.9). None of the other joint angles differed between trials ($p > 0.05$).

	MAX	MIN	AVE
Elbow	0.913	0.891	0.947
Shoulder	0.893	0.824	0.890
Hip	0.920	0.937	0.918
Knee	0.887	0.913	0.928
Ankle	0.957	0.850	0.951

Table 1. Intraclass correlation coefficients for maximum, minimum, and average joint angles (n=20).

DISCUSSION

The results of the Intraclass correlation indicate, that for the joints examined, the consistency of movements in repeated trials while rock climbing are high ($R > 0.820$). This is similar to the findings of Ford et al. (2007) who examined joint angles during jump landings. Also for most joints the lack of difference between trials suggests that subjects perform the movement the same in repeated trials.

The variation across trials for the ankle joint may be due to this joint being closest to main support of the body. Watts (2004) has noted that climbers typically use the feet to help provide support during climbing. Quaine et al. (1995) found that when one handhold was removed the load maintained by the hands only increased from 5-6 to 9-10 kg with both feet contributing support. Furthermore, unpublished data from our lab indicates that there is a greater amount of force supported by the feet than the hands. In the current study support was provided by one foot; thus variations in technique and supporting force of the foot could result in changes of the ankle joint movement and explain the differences in MAX ankle and AVE ankle across trials.

SUMMARY

The current study found that minimum, maximum, and average joint angles display a high degree of consistency for most joints during a repeated rock climbing movement based on ICC and lack of difference across trials. This information should provide additional knowledge for researchers investigating rock climbing movements.

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