A COMPARISON OF THE KINEMATICS OF LADDER CLIMBING USING RUNGS
VS SIDE RAILS

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INTRODUCTION

More than 20,000 American workers are injured, and over 100 die, every year as a result of falls from ladders (BLS 2005). Studies of the gait pattern of climbing on vertically tilted ladders have shown a large variation of the chosen method (McIntyre, 1983). ‘Lateral gait’ (i.e., synchronous ipsilateral hands and feet movement) and ‘diagonal gait’ (i.e., synchronous contralateral hand and foot movement) were reported as the most common climbing styles. However, an individual can change his/her climbing style even within the same ladder climb (Hammer 1992). Both Dewar (1977) and Hakkinen (1988) reported the use of both ladder rungs and rails as handholds. Bloswick (1992) studied vertical fixed ladder climbing, but only with the use of rungs.

The goal of this study was to contrast and compare the kinematics of climbing a fixed vertical ladder using two different climbing strategies: grasping rungs or grasping rails.

METHODS AND PROCEDURES

A custom-made, instrumented, fixed vertical ladder 10’ in length was constructed. Nine 16” wide rungs were spaced 12” apart (OSHA, 1910.27 Fixed Ladder standards). Ladder rungs and rails were 1-inch diameter cylindrical steel rods and were cleaned with steel wool before testing. The ladder rungs were attached to the ladder frame at the center post so the rungs could be mounted on 3-axis force and 3-axis moment transducers (AMTI® MC3 and ATI® Theta). Four of the rungs were instrumented – two for the feet and two for the hands. Twelve healthy subjects (6 males, 6 females, age: 21±2 years, height: 172±11cm, weight: 625.2±139.2 N and arm span: 150±4 cm) volunteered for this study. Subjects were instructed to climb a vertical fixed ladder at a comfortable speed using one of two climbing styles: grasping the rungs or the side rails. From a bipedal stance on the ground, subjects climbed 5 rungs, paused, and then return to the ground. Three repetitions of each treatment were conducted.

Bilateral optoelectric cameras (Optotrak 3020) recorded body kinematics at 100 Hz using 22 infrared markers placed on body landmarks including the head, acromion, lateral epicondyle, wrist, hand, greater trochanter, knee, malleolus, and feet. For the sake of brevity, we only report the descriptive statistics for the major joint motions. Paired, two-sided, t tests were used to compare joint motions in the two climbing styles, with p<0.05 being considered significant.

RESULTS

Figure 1 shows data from one climbing movement cycle from a representative trial of a subject beginning a climb while grasping the side rails. The cycle starts with the onset of right knee and hip flexion and ends in full knee and hip extension after climbing one step. In general, hip and knee flexion are out of phase with elbow and shoulder extension.
Figure 1. Sample data from a male showing contralateral style of vertical climbing using side rails. Positive (+) direction denotes flexion, negative (-) direction is extension.

This movement pattern was universally observed whether climbing with rungs or side rails in this study.

Mean (SD) range of joint motion data for one climbing cycle [mean (SD) time: 2.27 (0.35 s)] for the 12 subjects climbing with each climbing style (rungs vs rail hand-holds) are shown in Table 1. There were no significant difference in the ranges of motion used, although less variability was observed in climbing with rungs than with the rails. Greater kinematic variability in hip joint motion is noticeable when climbing with side rails. Variability in lower limb use was generally smaller than that with the upper limb.

### DISCUSSION

Although Table 1 gives a summary of the kinemetic data by climbing style, systematic differences in anthropometry (height and arm span) between the males and females will have increased the data scatter in that table. Joint ranges of motion may well be determined by stature and rung spacing. In the future we hope to expand group sizes and investigate the effect of anthropometry, age, ladder inclination and rail design on the kinematic and kinetic variables.

### SUMMARY

No significant differences were found in joint ranges of motion used to climb by grasping the rungs or the rails. Perhaps the kinematics were largely determined by rung spacing.

### REFERENCES


### ACKNOWLEDGEMENTS

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