LATERAL REACHING FROM FIXED LADDERS

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Introduction

The incidence rate of injuries among ladder users is very high, and though reaching laterally from a ladder is a common activity, it hasn't been studied thoroughly. Some studies have explored lateral reaching on stepladders (Clift and Navarro, 2002; Juptner, 1976) where the ladder may become unstable, however they do not address fixed ladders or the forces applied to the hands. **This aim of this study is to quantify the hand forces exerted by workers on fixed ladders as they perform a lateral reaching task.**

Methods

Independent Variables

Ladder Orientation: Vertical, 10° Forward Tilt
Handhold: Rung, Rail

Dependent Variables

Forces exerted by the hand on the ladder handhold (x, y, z, resultant)

Procedure

While standing with both feet on the ladder, subjects were instructed to reach to their left and touch a target that was one full arm span away from the centerline of the ladder. Subjects then returned back to the ladder after a short pause.

Two lateral reaching exercises (holding the left rail or holding the rung) were performed on two fixed ladder orientations (oriented vertically or pitched 10 degrees forward from vertical). There were three repetitions of each treatment. Orthogonal forces on the rungs or rail were recorded over the duration of the reach/return exercises. For data analysis purposes, the duration of a reach exercise was defined as the point when a left-lateral force was positive.

Forces were normalized by each subject's bodyweight, and sampled evenly over the duration of the reach/return exercise.

Subjects

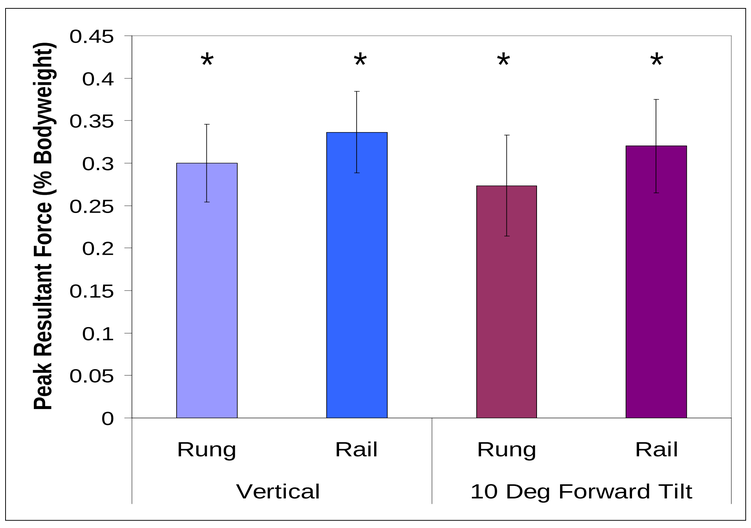
Twelve healthy subjects (6 males, 6 females) were recruited from the university community to participated in this study.

Gender	Height (m)	Weight (kg)	Age (yrs)	Grip Strength Right (kg)	Reach Span (cm)
Females (N=6)	1.62 ± 0.07	61.5 ± 6.1	25 ± 4	37 ± 3	139 ± 8
Males (N=6)	1.80 ± 0.09	79.7 ± 12.1	28 ± 4	62 ± 10	161 ± 11
All (N=12)	1.71 ± 0.12	70.6 ± 13.2	27 ± 4	50 ± 15	151 ± 15

Results

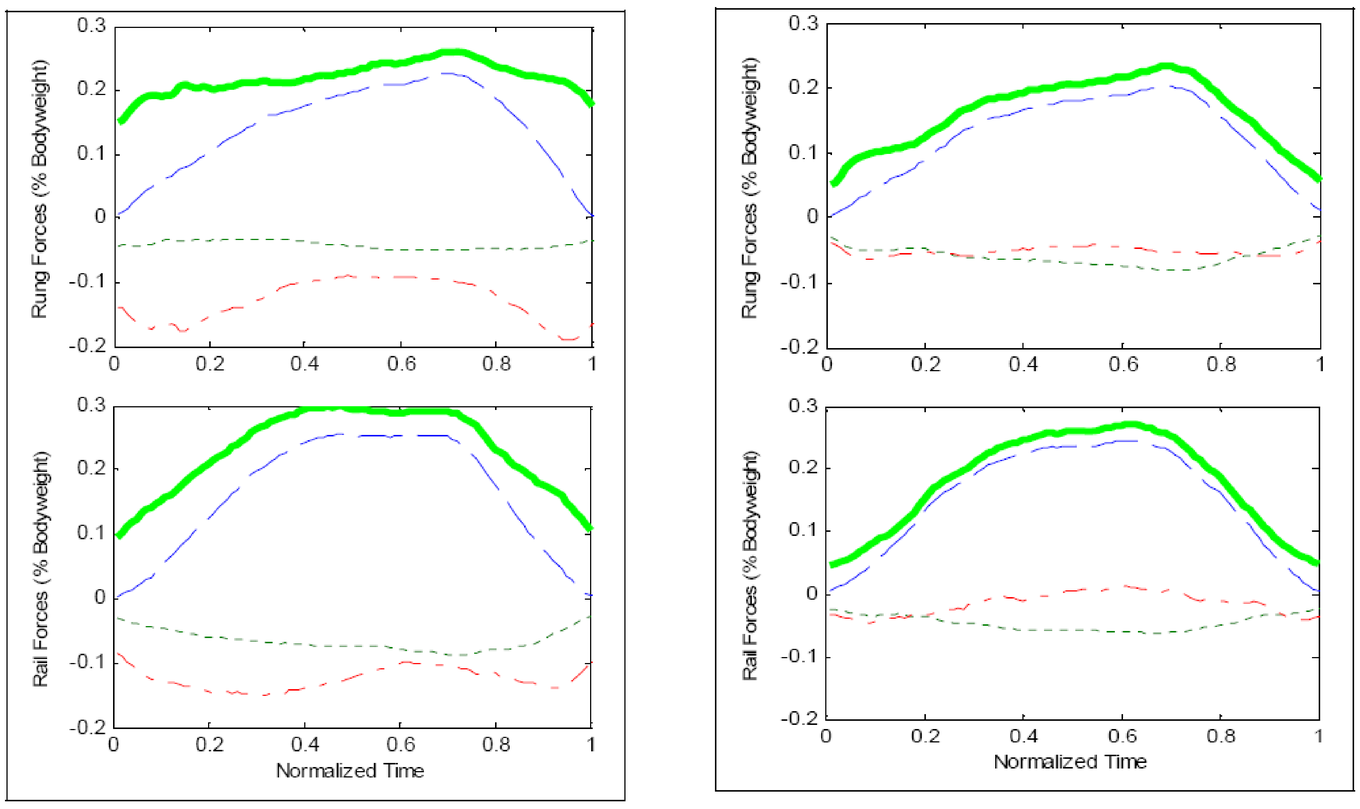
Peak Resultant Hand Force during Reach

Ladder Angle	Holding the Rung (kg)	Holding the Rail (kg)
Vertical	21.5 ± 6.8	23.7 ± 7.2
10º Forward Tilt	19.6 ± 6.8	22.7 ± 6.4



* Significant ($p<0.05$), repeated measures ANOVA

Mean Normalized Hand Forces (N=12) during Reach/Return Exercise



Component forces are dominated by lateral forces (x), but on the vertical rail, in/out (z) forces were larger during the initial reach and the return phase of the exercise. This was not the case for the tilted ladder.

Discussion & Conclusions

- A significant amount of force (27-34% BW) is required to perform a reach one arm span from the center of the ladder.
- Holding the rails may have resulted in greater force by allowing the body's center of mass to move more laterally.
- On a vertical ladder, the body's center of mass is outside the vertical plane. When reaching, a large inward force toward the ladder is needed at the beginning and ends of the reach task. On tilted ladders, the subject can balance their center of mass over their feet and use minimal inward force when reaching.
- These reach exercises were slow, mostly quasistatic, and if the subject were to increase speed, we would see larger forces on the hand. If the ladder is slippery, the required reaching force may exceed the grasp capability of the hand, or the required friction for the feet to resist lateral load.

References

Clift L & Navarro T (2002). *Ergonomics evaluation into the safety of stepladders: User profile and dynamic testing - Phase 2*. London, Health and Safety Executive.

Juptner H. (1976). *Applied Ergonomics*. 7(4): 221-223.

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