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MOTIVATION

- Every year, more than 20,000 American workers get injured by falls from ladders.¹
- The direct compensation and medical treatment costs associated with these falls are \$5.3 billion/year.²

OBJECTIVES

1. To determine the <u>time course of a fall</u> event by detecting changes in hand force, rung position, and upper limb muscle activities in response to a sudden upward loading of the rung simulating a ladder fall.

ROLES OF CUTANEOUS SENSATION AND GLOVES WITH DIFFERENT COEFFICIENTS OF FRICTION ON FALL RECOVERY DURING SIMULATED LADDER FALLS

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1. Typical <u>time course:</u>

Hand force increased first, followed by muscle onset. The rung movement started and ended afterwards. Weight drop



1. Time course:

- Muscles activated right after the hand force increased, before the rung moved.
 - > Detection of rung perturbation may be via cutaneous sensation (detecting increased pressure on the hand), not muscle spindle (detecting muscle length change).

2. Major muscles responding to rung

- To determine major muscles responding to a rung 2. perturbation.
- To examine the effect of gloves with different 3. coefficients of friction (COF) on a person's response time.

METHODS

Subjects:

- 13 right-handed healthy young adults
- 9 males and 4 females, age = 25 ± 5 years
- The nondominant hand was tested.

Procedure:

- To simulate a ladder fall, a sudden upward load was applied at a random time to a rung that subjects were grasping.
- Subjects were instructed to hold the rung with no extra effort at the beginning, and stop the rung from moving up when they detect the perturbation.





Polyester

(0.32)

Bare hand

(0.50)

Latex

(0.74)

2.1 Muscle reaction time:

The forearm muscles were activated first, followed by upper arm and shoulder muscles.



2.2 Peak EMG:

(%MVC)

FCU had the largest activation, followed by the latissimus dorsi and other forearm muscles.

100 Peak EMG 50

perturbation:

- The forearm muscles were activated the first.
- The forearm muscles and latissimus dorsi had the largest activation till rung stabilization.
 - > These muscles are primarily responsible for stabilizing the rung after perturbation.

3. Glove Effect:

- The bare hand resulted in the fastest muscle reaction, compared to the two gloves.
 - Cutaneous cues may have been detected earlier for the bare hand, resulting in faster muscle reaction time, compared to the two gloves.
- The rung moved the least for the latex glove, followed by the bare hand and polyester glove.
 - > High friction at the hand-rung interface may have helped stabilizing the rung with less rung displacement and muscle effort over time.



Dependent variables:

- Hand force increase time
- Rung movement time
- Muscle reaction time: earliest onset of muscle 3. activity among 8 muscles
- Rung stabilization time
- Rung displacement 5.
- Peak EMG
- Integrated EMG (iEMG) for each muscle



Triceps Biceps Pmajor Deltoid FCU EDC FDS Ldorsi

2.3 Integrated muscle EMG:

FCU had the largest activation over time, followed by the latissimus dorsi and other forearm muscles.



- Muscle reaction was faster for the bare hand than for the latex and polyester gloves.
- The rung moved the least for the latex glove, followed by the bare hand and polyester glove.
- Muscle effort (time integrated EMG) was minimum for the bare hand followed by the latex and polyester glove.



Functional applications:

- Risks of falling from ladders may increase:
 - 1) When detection of rung perturbation is hampered by sensory masking (cold temperature, paresthesia, thick glove use)
 - 2) For people with weakness in the forearm muscles and latissimus dorsi
 - 3) When low-friction at the hand-rung (due to liquid contamination, ice, or lowfriction glove) requires excessive muscle activation.
- Ladder falls may be prevented by:
 - 1) Enhancing cutaneous sensation
 - 2) Exercise programs that focus on the
 - forearm muscles and latissimus dorsi for people who work on ladders.
 - 3) Using high-friction rungs or gloves
- Consideration of the sensory flow, major muscles involved, and hand-rung interface design is important to reduce injuries from ladder falls.

Triceps Biceps Anterior deltoid Latissimus Flexor Flexor Extensor dorsi³ digitorum digitorum brachii brachii (top) carpi superficialis ulnaris Pectoralis communis major (bottom)

Statistical analysis:

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- <u>Time course of hand force increase, start/end of rung</u> movement, and the earliest muscle reaction was examined (repeated measures ANOVA).
- <u>Muscle</u> onset time, peak EMG, and integrated EMG across 2. 8 muscles were examined (repeated measures ANOVA).
- The glove effect was examined for each dependent 3. variable (repeated measures ANOVA).

Future Studies:

Future studies may include analysis of actual ladder fall in an experimental set up.

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