Ergonomic Design and Evaluation of Manual Cleco Pliers

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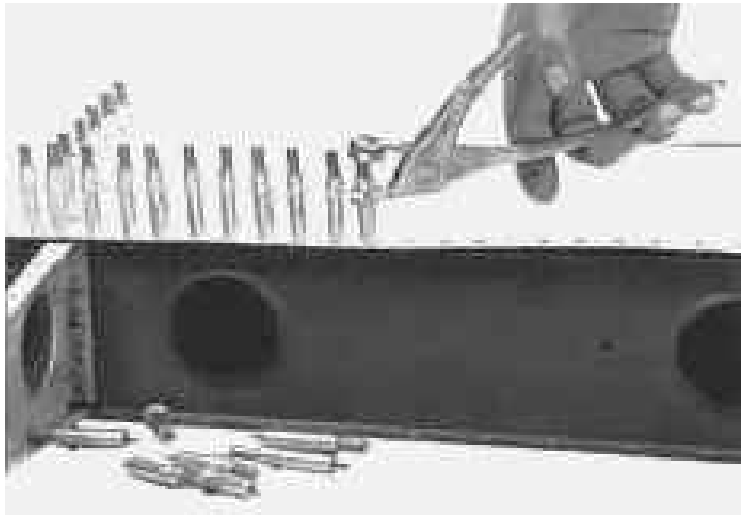
Agenda

- Introduction
  - ✓ Problem Statement
  - ✓ Objectives
  - ✓ Hypothesis
- Materials & Methods
- Results
- Conclusions

Cleco Pliers

- Cleco pliers are one of hand tools commonly used in aircraft industry to install fasteners to hold metal skins or frames together.



Problem Statement

- Workers often use Cleco pliers in awkward postures along with significant grip forces (10 to 30 lbs.), which could lead to undue musculoskeletal strain at the upper extremity.

Objectives

- Evaluate the effects of rubber grip and spring recoil on use of Cleco pliers in terms of:
  - ✓ muscle strain (EMG),
  - ✓ heart rate,
  - ✓ hand discomfort, and
  - ✓ subjective satisfaction.
- Develop ergonomic recommendations on the design of manual Cleco pliers.

Hypothesis

- Effects of rubber grip and spring recoil on grip force and time efficiency:

+: Positive effect; - Negative effect

Motion Elements	Rubber Grip		Spring Recoil	
	Force	Time	Force	Time
Positioning		+ (slipping prevention)		- - (hyper opening)
Grasping	++ (efficient transfer)		- (extra exertion)	
Releasing			++ (spring assistance)	++ (spring assistance)

Hypothesis (cont'd)

- Rubber grip $\rightarrow$ better transfer of grip force to the handles.
- Spring recoil $\rightarrow$ elimination of unnecessary hand motions.

$\Rightarrow$ Reduce the biomechanical stress at the upper extremity due to use of manual Cleco pliers.

Literature Review

- Padded handles facilitate even distribution of the forces of the hand, thus avoiding stress concentration (Fellows & Freivalds, 1991).
- Rubber grip on metal reduces the feeling of hand fatigue and hand tenderness (Freivalds, 1996).
- For a two-handed tool, the recoil of spring assists releasing of the handles (Eastman Kodak Co., 1983).

Apparatus

- EMG System,
- Heart Rate Monitor,
- Hand Discomfort Map,
- Satisfaction Questionnaire, and
- Simulated Workstation.

EMG System

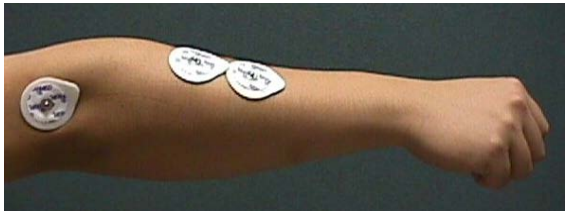
- FlexComp™ System

- Electrode Placement

Flexor Digitorum Superficialis (FDS)

Extensor Digitorum Communis (EDC)

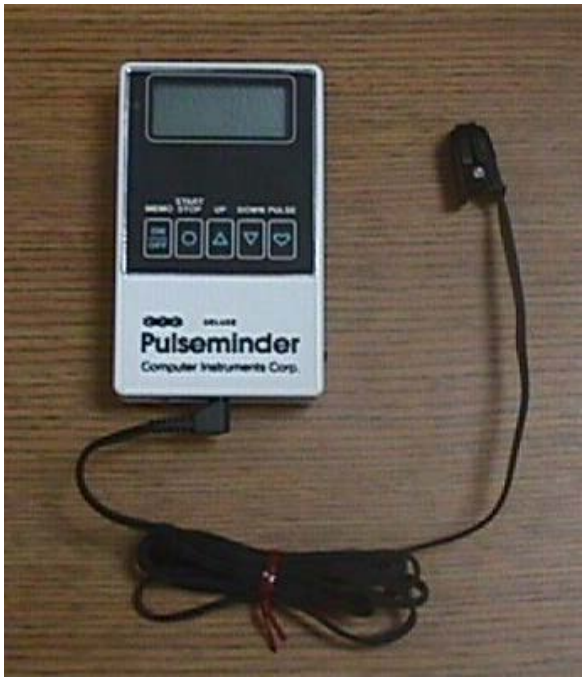
Flexor Carpi Ulnaris (FCU)



Extensor Carpi Ulnaris (ECU)

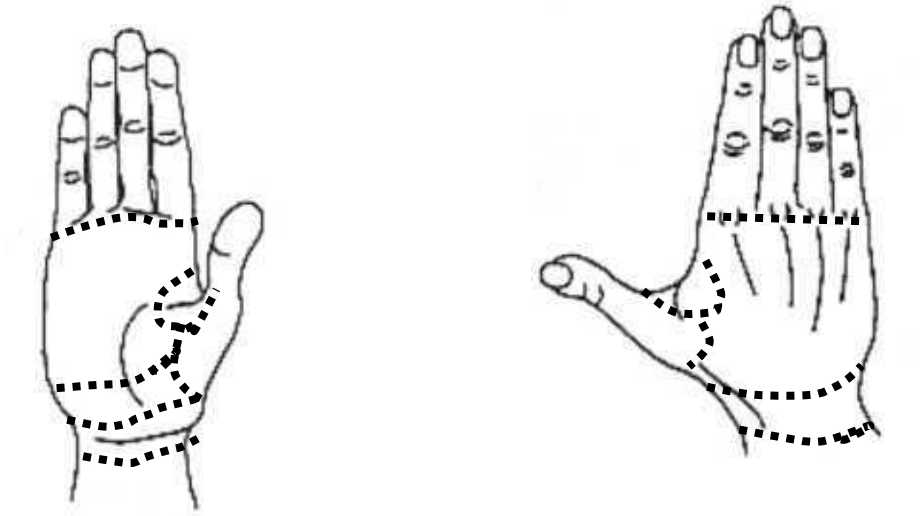
Heart Rate Monitor

- Pulseminder™ (Computer Instruments Co.)



Hand Discomfort Map

- Evaluation on 6 hand regions of the palm and dorsum each.
- Used the modified Borg scale of 0 (no discomfort) to 10 (extremely uncomfortable).



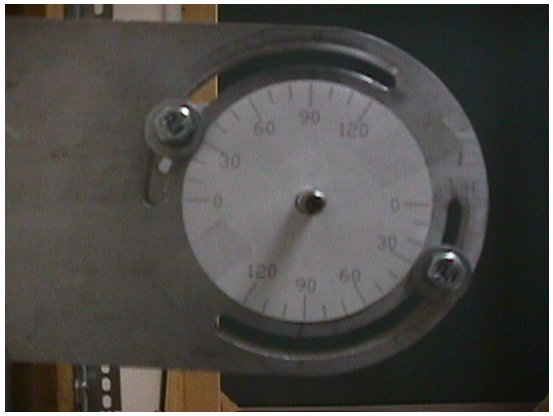
Satisfaction Questionnaire

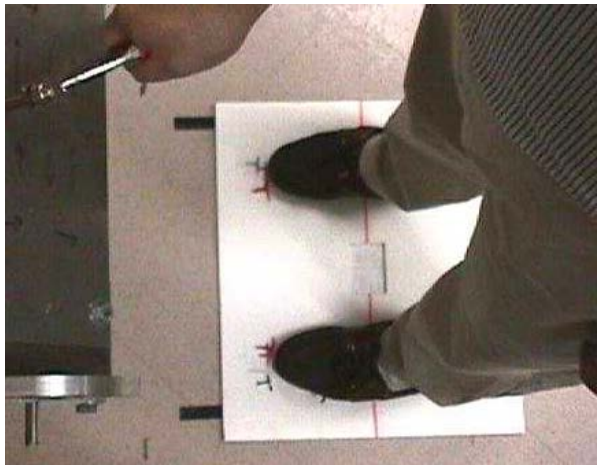
- Subjective evaluation on 8 design parameters.

Design Parameters	 conventional	 w/ rubber grip
Grip Span	too narrow — too wide; satisfactory	too narrow — too wide; satisfactory
Handle Texture	too rough — too smooth; satisfactory	too rough — too smooth; satisfactory
Grip Force Requirement	too small — too large; satisfactory	too small — too large; satisfactory

Simulated Workstation

- Cleco plier workstation
  - ✓ Height Adjustment: 29” to 43”
  - ✓ Angle Adjustment: 0° to 120°
  - ✓ Foot Marker: 10” to 20”





Participants

- 11 workers from Cessna:

Gender	Female			Male		
Hand Size *	Small	Medium	Large	Small	Medium	Large
	≤ 33%	34–66%	≥ 67%	≤ 33%	34–66%	≥ 67%
N	2	2	2	2	2	1

* Hand breadth at the metacarpals

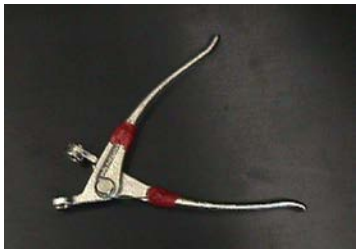
- Selection Criteria
  - ✓ Age: 18 years of age or older.
  - ✓ Health conditions: No history of injuries at the hand, wrist, or forearm.
  - ✓ Work experience: At least one-year work experience using manual Cleco pliers.

Design of Experiment

- Two-way (4×3) within-subject design; subject is nested within gender and hand size.
  - ✓ 4 plier designs

conventional

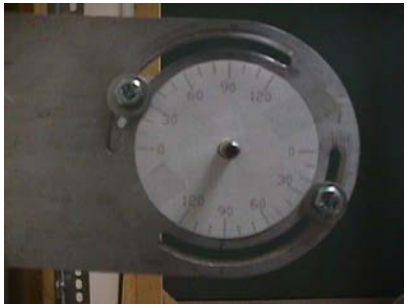
with rubber



with spring

with both rubber and spring

  - ✓ 3 metal frame angles: 0°, 60°, and 90°.



Procedures

- 3 sessions lasting for 2 hours.

No	Session	Time (unit: hr)
1	Pre-work	0.5
2	Work	1.2
3	Post-work	0.3

Pre-work Session

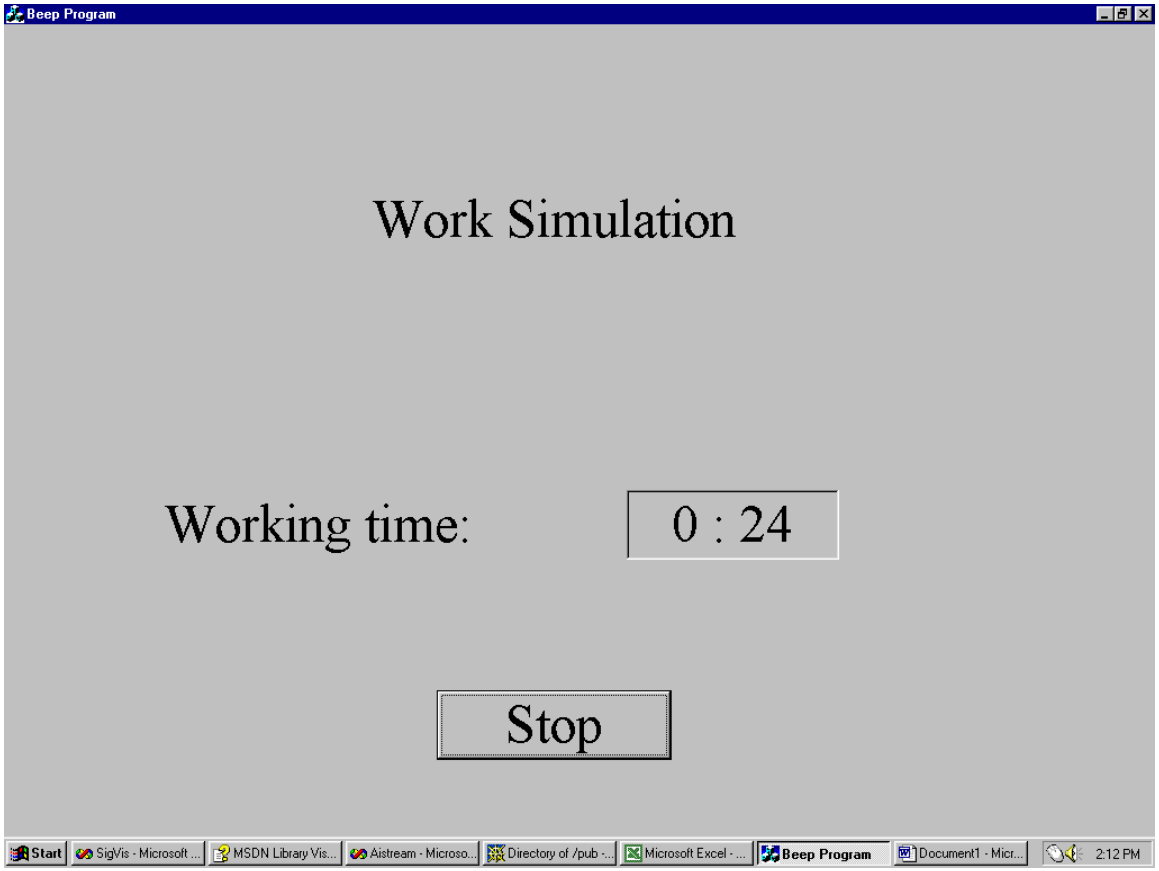
No	Activities	Remarks
1	Informed consent	-
2	Demographic info.	-
3	Workstation height adjustment	posture control
4	Foot marker alignment	
5	Instructions to participant	-
6	Exercise (5 min.)	-
7	Electrode placement	-
8	EMG signal acquisition (10 lbs.)	for normalization
9	Pulseminder attachment	-

Work & Post-work Sessions

Session		Measurements
Work *	Before	Heart rate
		Hand discomfort
	During	EMG signal
	After	Heart rate
		Hand discomfort
Post-work		Design satisfaction questionnaire

* Work speed and work-rest period were controlled by computer.

Speed Control



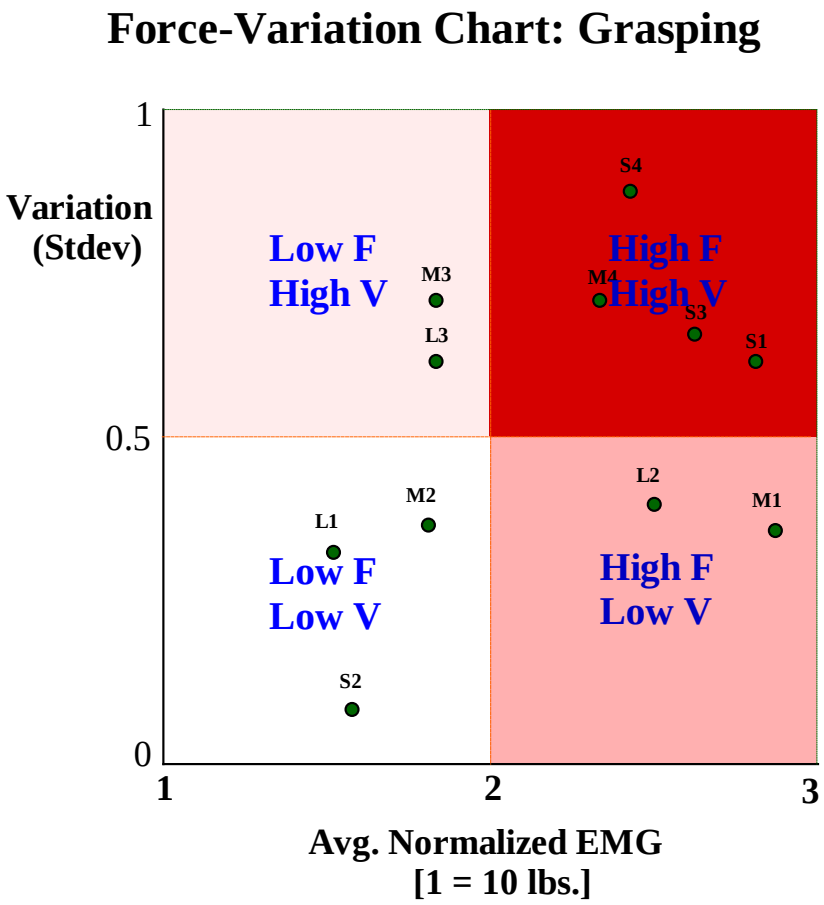
EMG Analysis

- ANOVA results indicate subject is the most significant factor. (*: $p < 0.05$; **; $p < 0.01$)

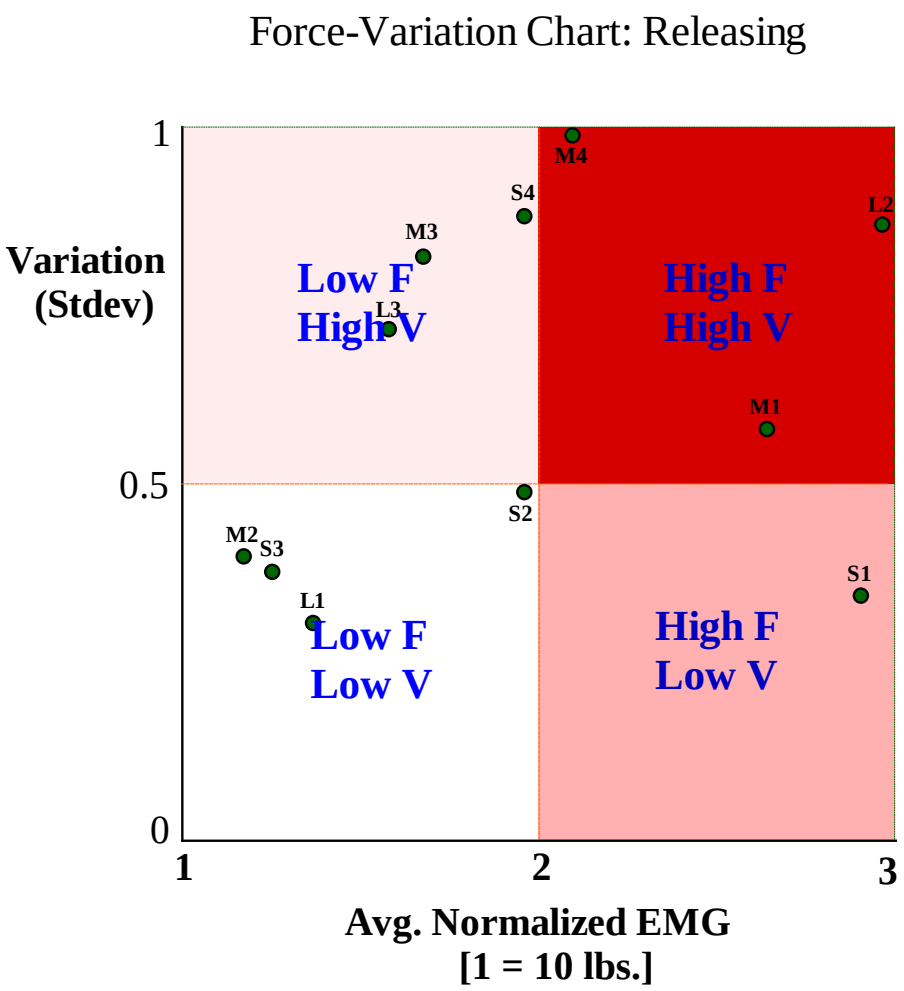
No	Source	Grasping	Releasing	Positioning	
		FDS	EDC	FCU	ECU
1	Gender (G)				
2	Hand Size (H) [G]				
3	**Subject (S) [H, G]**	**	**	**	**
4	**Plier Design (P)**	*		**	**
5	**Angle (A)**		**	*	**
6	G × P				
7	G × A		**		**
8	H [G] × P				
9	H [G] × A				
10	S [H, G] × P				
11	**S [H, G] × A**	*	*	*	
12	**P × A**	**	**	**	**

Subject Classification: Grasping

- Classified subjects into quadrant groups based on the average and s.d. of normalized EMG values.

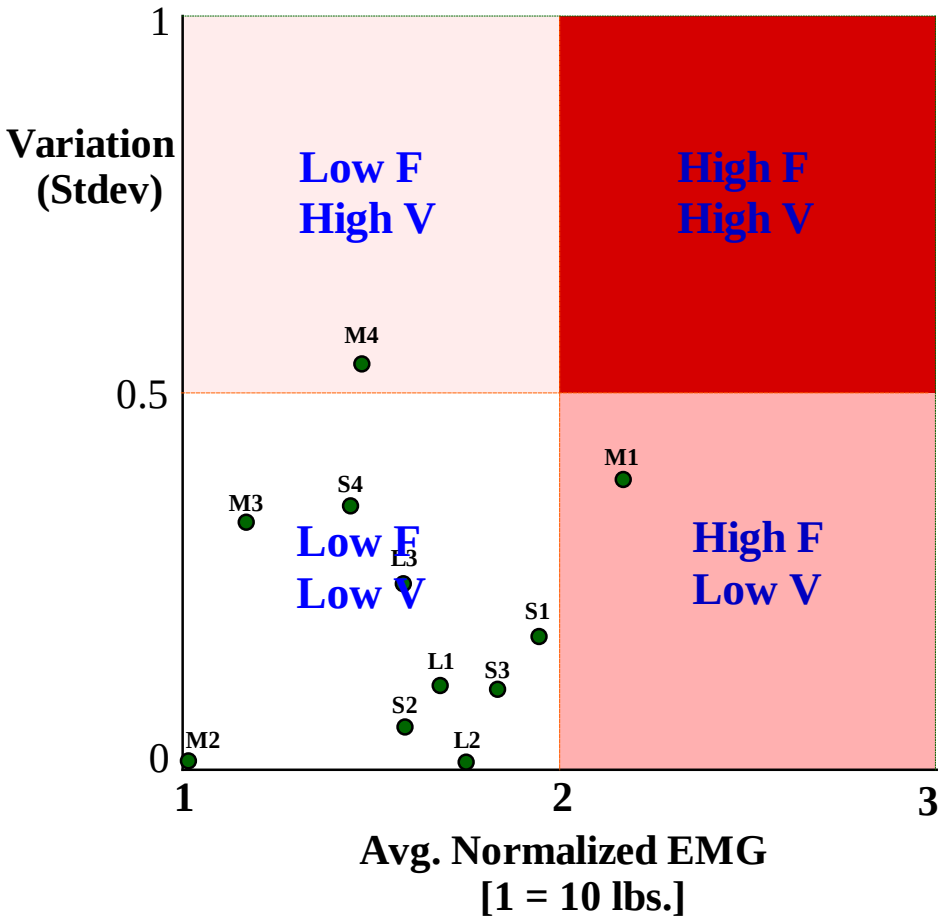


Subject Classification: Releasing



Subject Classification: Positioning

Force-Variation Chart: Positioning



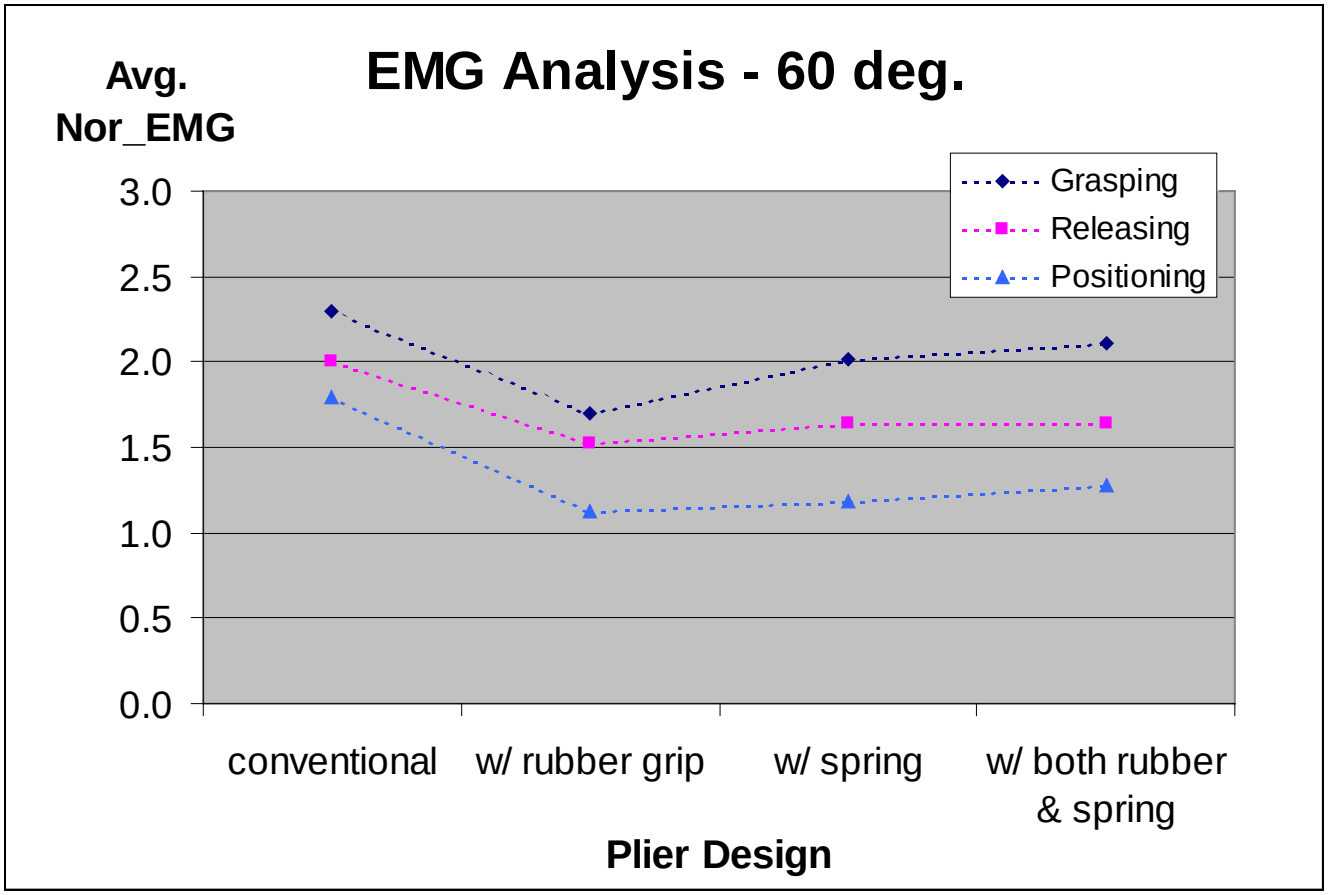
Subject Classification: Summary

- Distinguished between workers having proper skills and those requiring ergonomic training.

Subject	Gender	Experience (yrs)	Grasping	Releasing	Positioning
S1	F	2.5	1	2	
S2	**F**	**3.5**			
S3	M	4.5	1		
S4	M	4.0	1	3	
M1	F	1.5	2	1	2
M2	**F**	**4.0**			
M3	M	5.0	3	3	3
M4	M	10.0	1	1	
L1	**F**	**10.0**			
L2	F	2.0	2	1	
L3	M	3.0	3	3	

Plier Design Effect

- Significantly lower grip forces were used for pliers with rubber grip.



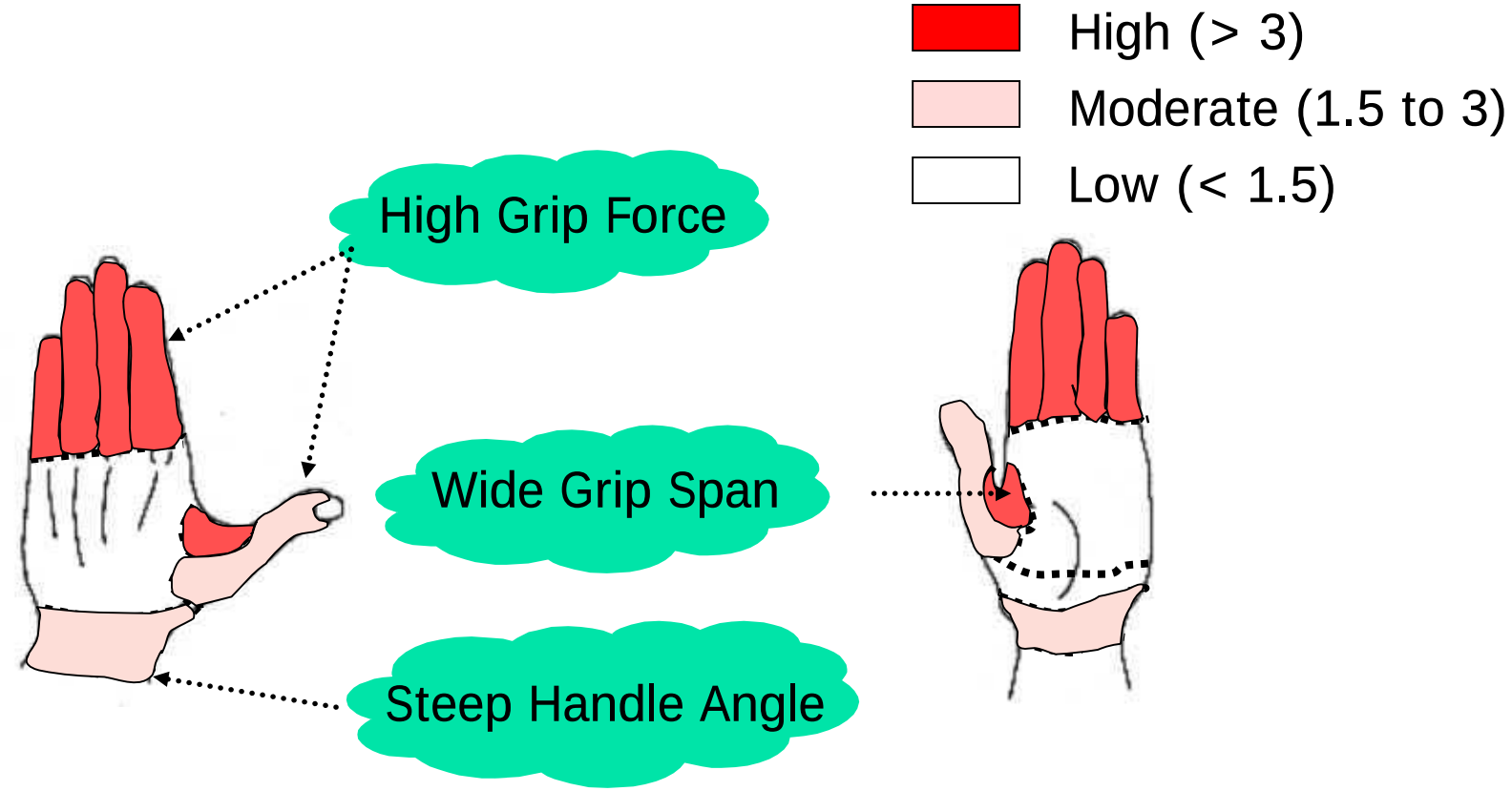
Heart Rate Analysis

- No significant factors are found affecting heart rate.

$\Rightarrow$ The participants did NOT experience any significant increase in whole-body fatigue.

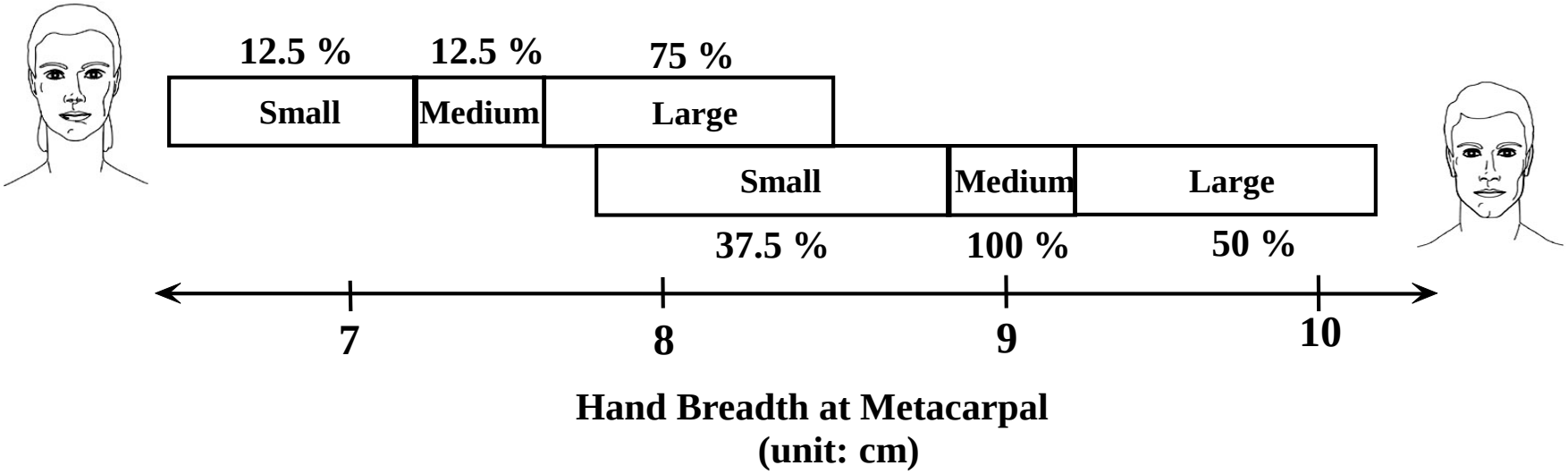
Hand Discomfort Analysis

- Identified hand regions showing a significant increase of discomfort from using Cleco pliers.



Design Satisfaction Analysis

- Grip span (4”) was evaluated as too wide, especially for small-hand people.

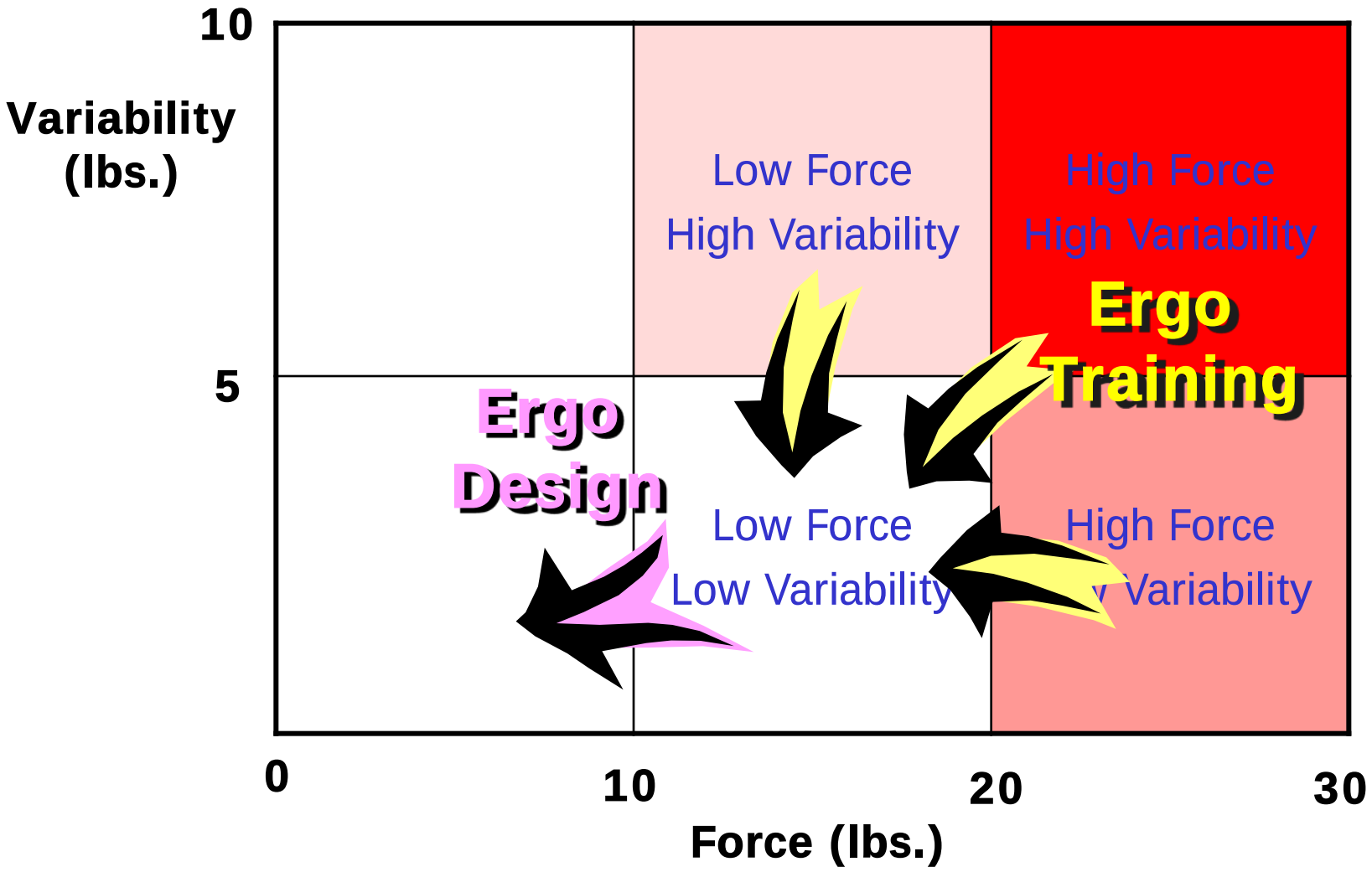


- Handle texture satisfaction was increased from 18% to 82% by use of rubber grip.

Conclusions

- EMG measure may be a valid tool to evaluate the skill of a worker using Cleco pliers.
- Ergonomic work methods of the pliers should be established and workers be trained accordingly.
- Use of rubber grip on the plier handles is recommended.
- Three Cleco plier features require ergonomic redesign: grip span, force mechanism, and handle orientation.

Ergonomic Strategy



Acknowledgments

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