Evaluation of the WristCorder™: A Hand-Forearm Motion Analyzer

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Agenda

- Introduction
  - ✓ WristCorder™ System
  - ✓ Objectives
- Materials & Methods
- Evaluation Results
- Conclusions

Problem Statement

- Improper hand-forearm motions have been identified as a major risk factor of UE-MSDs.
- A valid goniometric instrument to measure hand-forearm motions in multiplanar and dynamic environments has been needed for effective control and assessment of UE-MSDs at work.

WristCorder™ System

- 3D hand-forearm motion analyzer, developed by MotionWatch LLC.
- Hall-effect sensors attached at the glove.
- Attachable recording device: 10 Hz for 8 hrs.
- Statistical analysis of hand-wrist motion.

Objectives

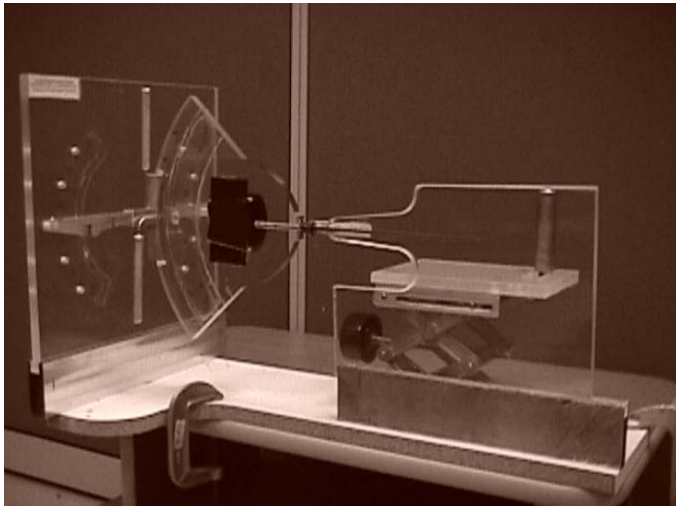
- Evaluate the linearity, sensitivity, and reliability of WristCorder™.

- Develop a fixture to evaluate WristCorder™ along three axes:
  - ✓ Wrist Flexion/Extension (F/E),
  - ✓ Wrist Radial/Ulnar Deviations (R/U), and
  - ✓ Forearm Pronation/Supination (P/S).

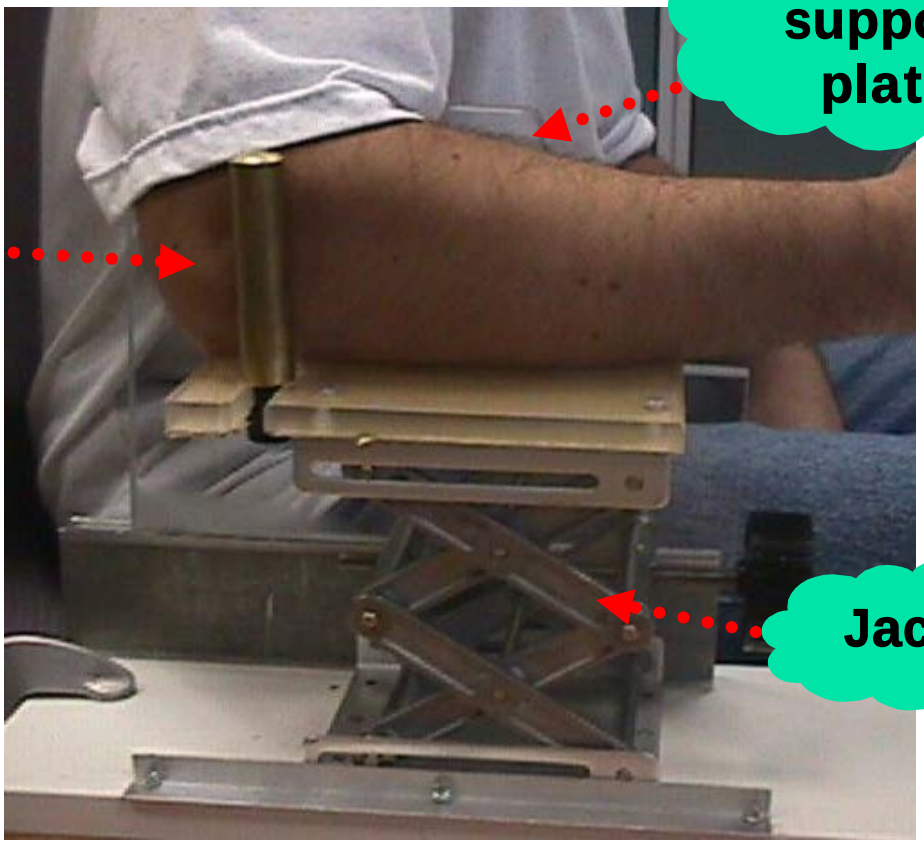
Materials & Methods

- WristCorder™: Two glove sizes (medium; large).

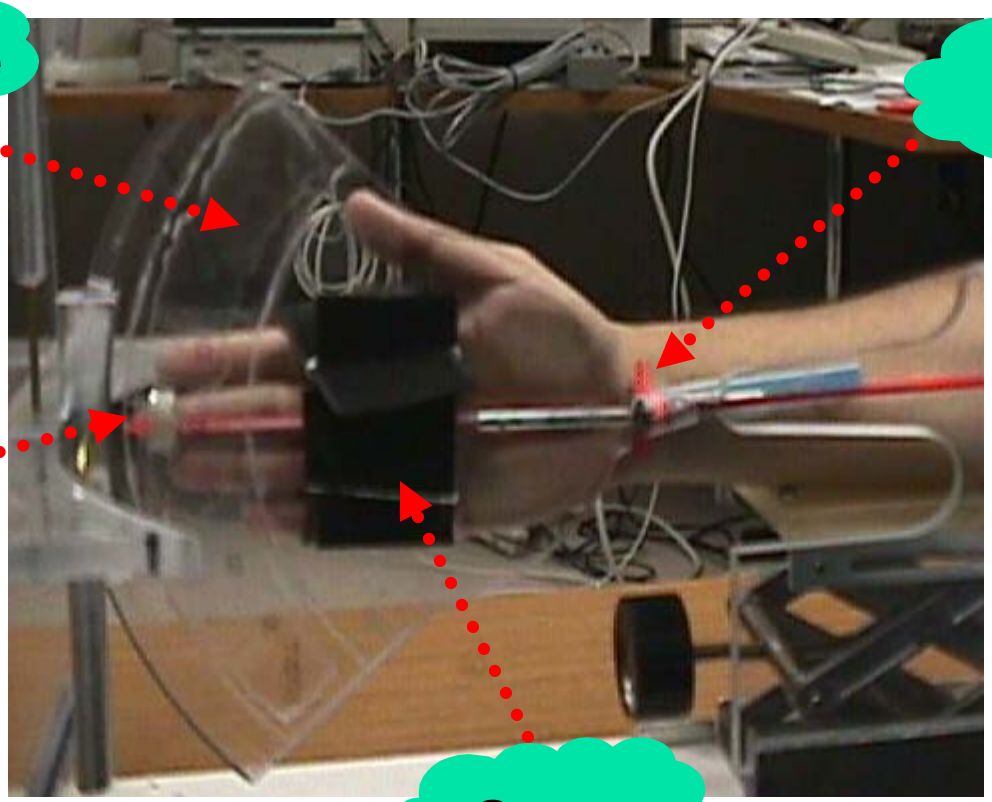
- Tri-axial Hand-Forearm Fixture
  - ✓ Forearm section
  - ✓ Hand section
  - ✓ Angle-control section



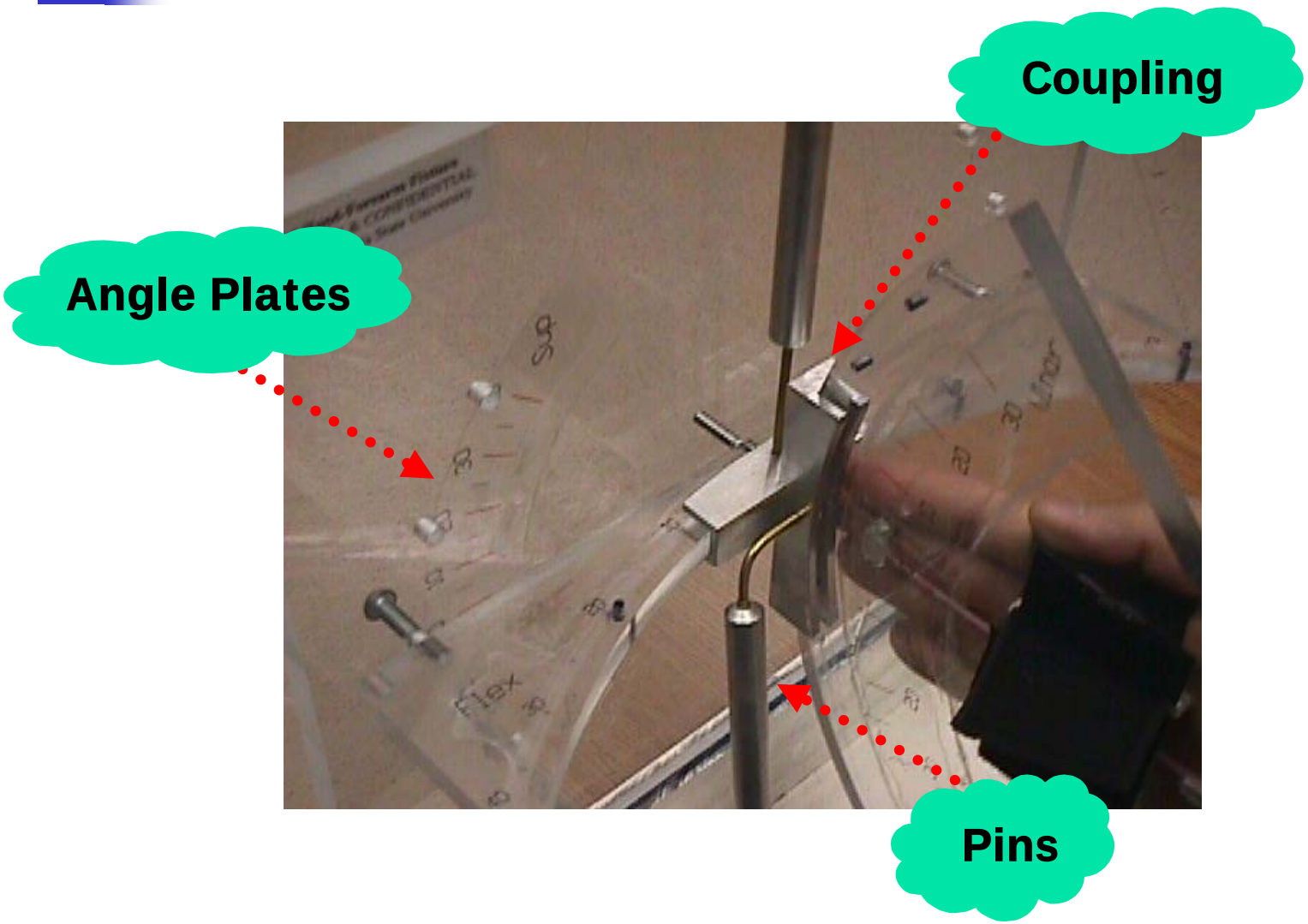
Forearm Section



Hand Section

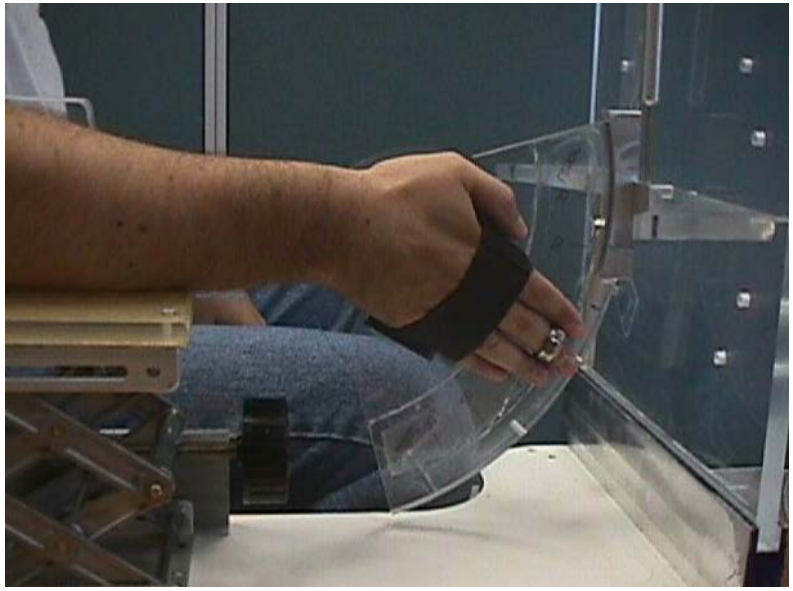


Angle Control Section

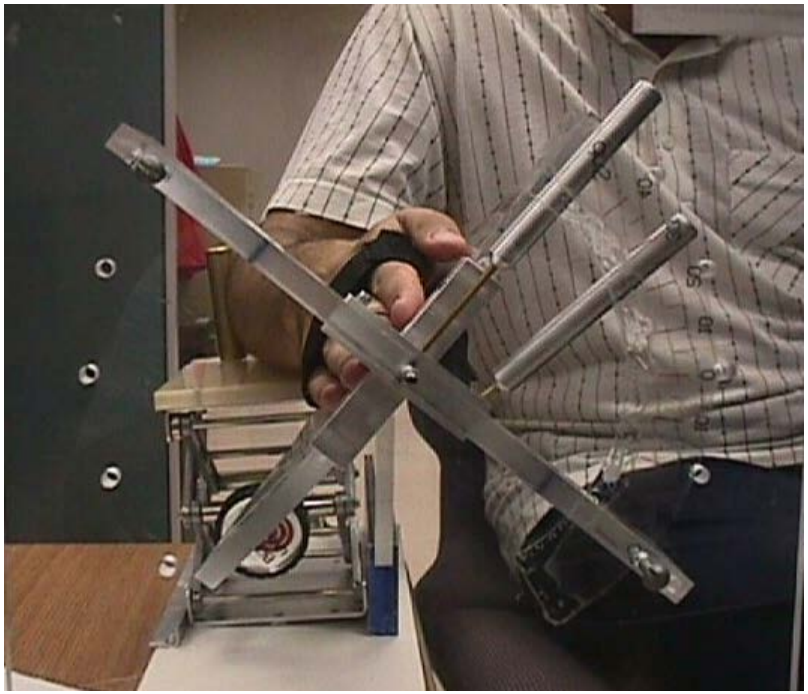


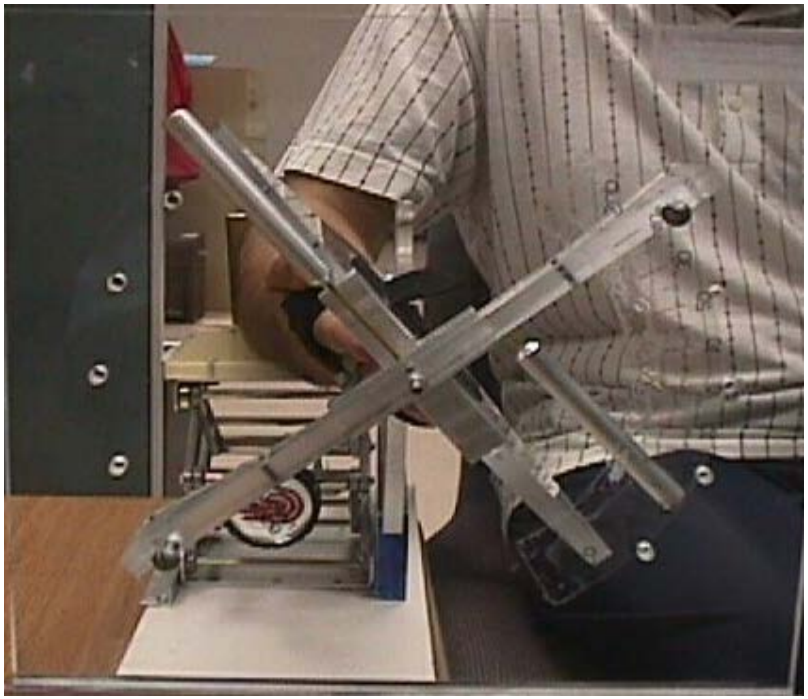
Flexion/Extension

Radial/Ulnar Deviation



Pronation/Supination





Participants

- 8 participants (4 for each glove size).

Hand Size	Medium	Large
Hand circumference (at the metacarpals)	16.1–17.4 cm	19.1–22.4 cm
Forearm circumference (relaxed)	19.6–25.0 cm	22.0–31.0 cm

- Selection Criteria
  - ✓ Age: 18 years of age or older.
  - ✓ Health conditions: No history of injuries at the hand, wrist, or forearm.

Design of Experiment

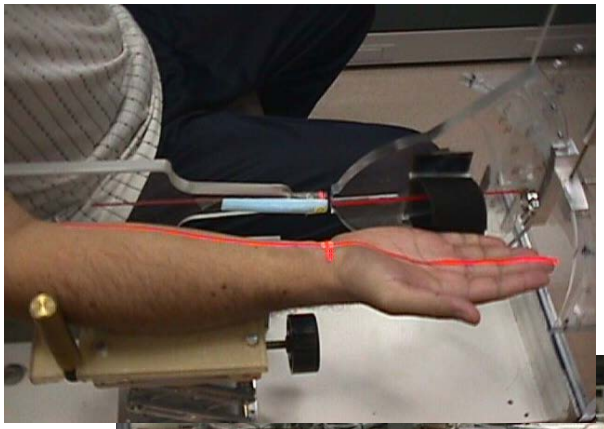
- Uniplanar movements were measured by using WristCorder™ at five different positions for each dimension with three repetitions.

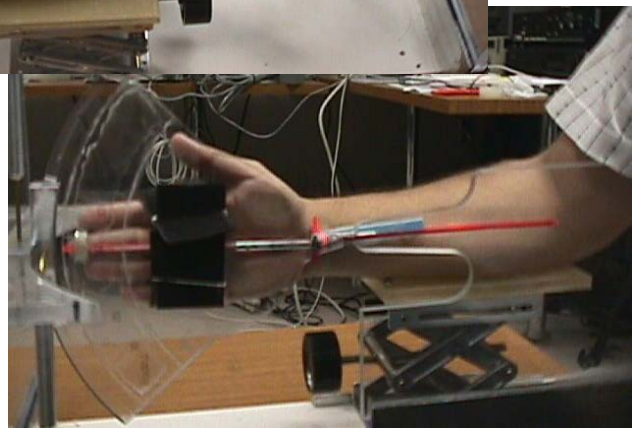
Dimension	Positions
F/E	F40°, F20°, neutral, E20°, E40°
R/U	R10°, neutral, U10°, U20°, U30°
P/S	P40°, P20°, neutral, S20°, S40°

- The experiment conditions were randomized within subject.

Procedures

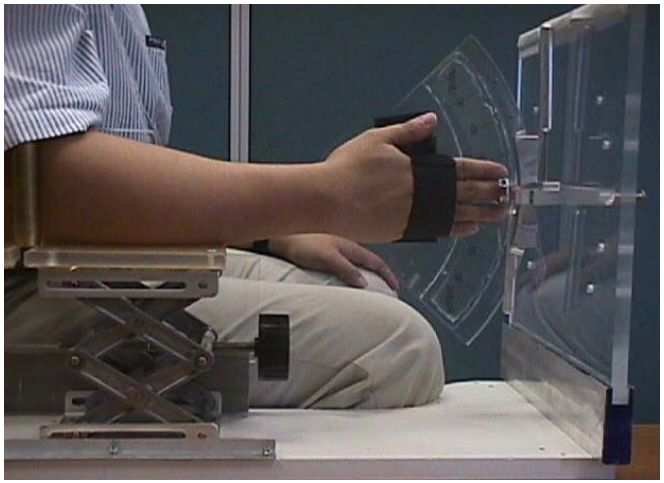
- The flexion/extension sensor of WristCorder was aligned with the third metacarpal and dorsal center of the wrist.
- A tape strip was placed on the ventral side of the hand-forearm, passing through
  - ✓ the middle finger,
  - ✓ the center of the wrist,
  - ✓ the middle of the forearm.





Procedures (cont'd)

- Each participant was seated in a chair adjusted at the elbow height; the hand, wrist, and forearm were restrained securely.



- Measurements were made while the hand was held at certain positions on the fixture.

Results - Linearity

- Regression analysis indicated that sensor values and angular values have strong linear relationships across all movement directions.
  - ✓ F/E: R^2 =.80 ~ .99
  - ✓ U/R: R^2 =.93 ~ .99
  - ✓ P/S: R^2 =.85 ~ .99

Results - Sensitivity

- ANOVA analysis indicated that the sensitivity of each sensor significantly varies depending on movement direction ($p < .05$).

- The minimum angles that WristCorder™ can measure are
  - ✓ F/E: 0.52º / 0.38º
  - ✓ U/R: 0.91º / 0.61º
  - ✓ P/S: 2.44º / 3.26º

Results - Reliability

- ANOVA analysis indicated that the sensor values were stable across the three repetitions.
- The standard errors of measurement (SE_{meas}*) of WristCorder™ are
  - ✓ F/E: 0.89º
  - ✓ U/R: 0.83º
  - ✓ P/S: 2.25º

* $SE_{meas} = SD_{inter-subject} \times \sqrt{1 - r_{btwn-repetition}}$ (Norkin & White, 1995)

Conclusions

- The hand-forearm fixture enabled the accurate control of positioning of the hand-forearm at a designated angle in 3D.
- WristCorder™ produced a strong linear relationship with movements of the hand-forearm within the tested angle ranges.
- Sensitivity of the F/E and U/R sensors was less than 1° and that of the P/S ranged from 2.5° to 3.5°.
- Standard deviations due to measurement error were about 1° for F/E and U/R and 2.5° for P/S.

Acknowledgements

The WristCorder evaluation project was funded by MotionWatch LLC.