Introduction: Assessment of the global wrist motion is important to diagnose and treat motion impairment after injuries to the wrist. Although most daily activities can be performed within a limited arc, a host of tasks require a greater range of wrist motion. It is a common observation that finger joints move synergistically with wrist movement, i.e. wrist flexion is accompanied by finger extension and vice versa. Su et al. showed that there exist linear relationships between wrist joint movement and distal interphalangeal (DIP), proximal interphalangeal (PIP) and metacarpophalangeal (MCP) joint movements [1]. However, it is unknown how finger joint configuration influences the motion capability of the wrist. The aim of the study was to investigate the effect of finger constraints on the maximum circumduction movement of the wrist. We hypothesized that wrist motion capability with finger joint constrained would be less than that with freely movable finger joints.

Materials and Methods: Fifteen male right-handed subjects (age 27.0 ± 6.2 years, height 174.3 ± 15.0 cm, weight 79.2 ± 4.6 kg) without neuromusculoskeletal disorders of the upper extremity participated in the study. The wrist motion was captured by a motion analysis system (VICON 460, Oxford, UK) based on surface makers. Six light reflective markers with a diameter of 5 mm attached on two isosceles plastic triangles (base = 4 cm) were placed on the dorsal aspect of the forearm and the hand with double adhesive tape. The two marker sets defined the coordinate systems for the forearm and hand. The forearm was stabilized in the custom mount in a neutral pronation/supination. The subject was instructed to perform clockwise circumduction of the wrist during which the subjects forced the wrist to its maximum boundary at a self-selected speed. Each subject performed maximal circumferential wrist movements under four finger conditions: unconstrained fingers, holding a large (diameter 50 mm, 0.27 N) cylinder, holding a small (diameter 25 mm, 0.19 N) cylinder, and closing the hand to a fist. For the unconstrained finger condition, the finger joints were relaxed and allowed to move freely during wrist circumduction. To quantify the wrist motion capability, we constructed the wrist circumduction envelope with angular plots in flexion/extension (FE) and radial/ulnar deviation (RUD). The ranges of motion in FE and RUD and the envelope area were calculated. Repeated measures one-way ANOVA were used to analyze the effect of finger condition on the ROM and area (α=0.05).

Results: Finger constraints significantly reduced motion ranges in flexion and ulnar deviation, but not in extension or radial deviation. In comparison to the unconstrained finger condition, the motion ranges in flexion decreased by 13%, 16%, and 27% for the large cylinder, small cylinder and fist conditions, respectively (p < 0.01, Figure 1). The wrist ROM in flexion/extension were 151.3 ± 12.8, 141.9 ± 14.2, 140.2 ± 10.2, and 129.7 ± 10.4 degrees for the unconstrained, large cylinder, small cylinder, and fist conditions, respectively. The range of ulnar deviation was reduced by 10% for the large and small cylinder conditions, and 11% for the fist conditions (p < 0.05). The ROM in radial/ulnar deviation were 80.0 ± 9.1, 73.3 ± 9.6, 74.3 ± 11.9, and 73.0 ± 14.4 degrees for the unconstrained, large cylinder, small cylinder, and fist conditions, respectively. The envelope area for the unconstrained finger condition was greater than that for any of the constrained finger condition (p < 0.01). The overall mobility in FE and RUD, as quantified by the area of the circumduction envelope, decreased by 15%, 15%, and 23% for the large cylinder, small cylinder and fist conditions, respectively.

Discussion: Constraining fingers in static flexion posture reduces wrist flexion and ulnar deviation, but not extension or radial deviation. We confirmed our hypothesis that wrist ROM was reduced by finger constraints when holding a cylinder or making a fist. Wrist flexion produces considerable tendon excursions of the extensor digitorum communis, extensor indicis proprius and extensor digiti minimi, generating increasing passive resistance against wrist flexion. Furthermore, wrist flexion, together with flexed fingers, largely shortens the flexor muscles, diminishing the force production capability of the flexor muscles. The limit of wrist flexion is reached once the active force production of the flexors cannot overcome the passive resistance of the stretched extensors. However, wrist ROM in extension is not decreased by the constrained finger flexion because a flexed finger posture is synergistic with wrist extension in reducing the excursions of both the flexors and extensors. Likewise, the mechanism of passive resistance can also explain the decrease of wrist ROM in ulnar deviation. The thumb was in a flexed posture when making a fist or holding the cylinders. Ulnar deviation stretches the already elongated tendons of the abductor pollicis longus, extensor pollicis longus and extensor pollicis brevis, producing large passive resistance and thus limiting the ROM towards ulnar deviation. The findings of this study have ergonomic and clinical implications. Work related tasks often require a tight grip of objects while the wrist goes through a wide arc of motion. Our results showed a loss of 27% flexion and 11% ulnar deviation when the fingers are constrained in a fist condition. Clinical measurement of the wrist mobility is critical to diagnose and treat motion impairment after injuries to the wrist. As wrist ROM is strongly influenced by finger configuration, evaluation of wrist ROM should consistently be standardized concerning the finger joint condition.