

JOINT CONTRIBUTION TO FINGERTIP MOVEMENT DURING DIRECTIONAL TAPPING

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INTRODUCTION

Computer use has often been associated with upper extremity musculoskeletal disorders (UEMSDs).

The prevalence of UEMSDs in the shoulder and neck region among computer users is even higher than the hand/arm region [1,2,3]. Previous biomechanical studies of computer users have been limited to the study of finger and wrist joint, movement in the sagittal plane, or tapping on a single key switch [4,5,6]. The goal of this study was to compare the biomechanical loading on the proximal vs. distal joints by calculating the contribution from the finger, wrist, elbow and shoulder joints to fingertip directional movements in three-dimensional (3-D) space.

METHODS

Six young (mean (sd) age 28.3 (\pm 2.0) years) adults, three women and three men tapped on a stand-alone number keypad with their right index finger at the speed of 3 taps per second. Participants tapped in three conditions: (1) on a single key-switch (the number key 5); (2) in a left-right direction (back and forth on the number key 4, “left”, and 6, “right”); (3) in an up-down direction (back and forth between the number key 2, “down”, and 8, “up”). No forearm or palm support was provided.

Three-dimensional kinematics of the upper extremity were recorded using an active-marker infrared motion analysis system (Optotrak Certus System, Northern Digital, Ontario, CN). Four clusters of three markers secured on a rigid plate were mounted on the hand, forearm, upper arm and torso. A single marker was attached on the fingertip of the right index finger. Locations of these markers in 3-D space were recorded at 200 samples per second. All kinematic data were low pass filtered digitally using a fourth order Butterworth filter with a

cutoff frequency of 10 Hz and a zero phase shift. The finger was approximated as a single segment with the length spanning the metacarpophalangeal (MCP) joint center to the fingertip.

The MCP, wrist, elbow and shoulder joint contributions to the fingertip movement were calculated by multiplying the relevant joint excursion with the effective moment arm of the fingertip about the joint axes. First the vector from the joint rotation center to fingertip was calculated, and the effective moment arm was the vector projection to the plane that was perpendicular to the rotating axis. The coordinate axes orientations were as follows: anterior (+) and posterior (-) of the x axis, medial (+) and lateral (-) of the y axis, and superior (+) and inferior (-) of the z axis. Fingertip movement was defined as the distance moved in 3-D axis from the maximum position on the z axis to the maximum force applied on the key switch.

RESULTS AND DISCUSSION

Joint contributions to fingertip movement in the z direction (vertical) were similar between single key and left-right tapping, and the wrist contributed the most among all the joints (Figure 1). Joint contributions to fingertip movement changed substantially for up-down tapping. The shoulder and the MCP joints produced the most fingertip vertical movement for the “down” keystrokes. The wrist and elbow joints contributed positively (fingertip movement due to the joint was in the same direction as the measured fingertip movement) while the shoulder contributed negatively to the fingertip vertical movement for the “up” keystrokes. For fingertip movement in the y direction, shoulder and wrist were the major contributing joints, while the shoulder was the dominant contributing joint for fingertip movement in the x axis.

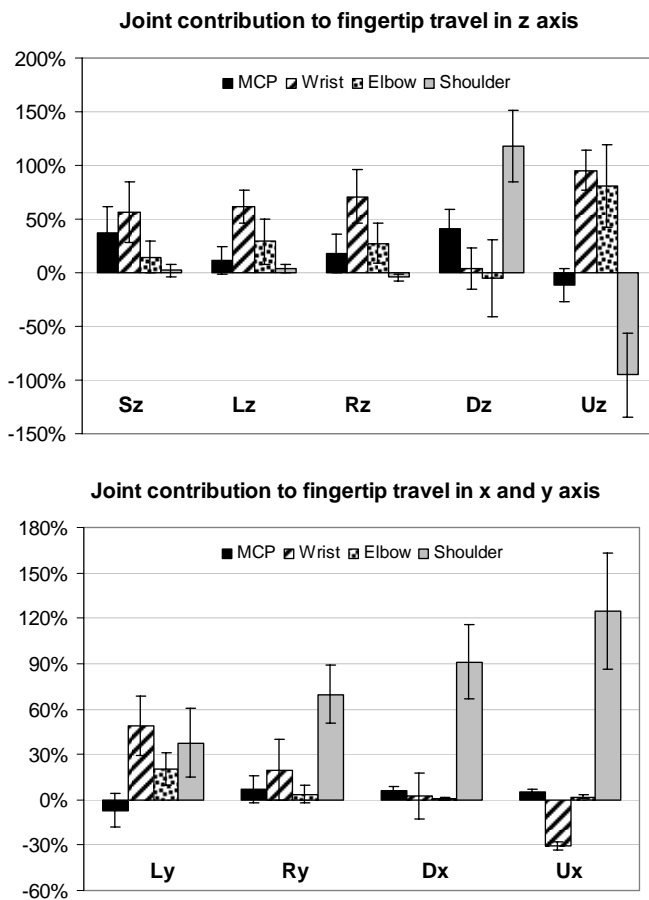


Figure 1: Percentage of joint contribution to fingertip three-dimensional movement averaged across subjects for the three experimental conditions. S – single key switch, L – left, R – right, D – down, U – up.

The various contributions across the different tapping conditions were consistent with the joint constraints and anthropometric characteristics of the upper extremity kinematic structure. We have modeled the upper extremity with four rigid segments with joints that limit the degrees of freedom to nine. In the typing postures with the forearm fully pronated and the elbow flexed at a right angle, all joints contribute to almost pure vertical movement of the fingertip through flexion and extension except for the shoulder, which produced both vertical and forward/backward motion in the x axis of the fingertip. During the up-

down movements, the system takes advantage of the shoulder flexion/extension to move the finger along the x axis.

During the “down” keystrokes, the wrist contributed very little to the vertical movement but the shoulder contributed significantly. During the “up” keystrokes, pure shoulder flexion contributed to fingertip movement in the positive x and z directions, therefore the wrist and the elbow joints flexed in order to keep the fingertip on the same horizontal level as the keypad. For the left-right movements, abduction/adduction of the wrist and shoulder as well as internal/external rotation of the shoulder moved the fingertip to the two locations.

CONCLUSIONS

This study determined the MCP, wrist, elbow and shoulder joint contribution to fingertip movements in 3-D space. The upper extremity was modeled as a nine-degrees-of-freedom system while tapping at three conditions. During single key switch tapping, MCP and wrist contributed the most to fingertip vertical movement, while the shoulder joint became the dominant contributing joint during directional tapping, especially in up-down movements. These findings provide evidence for the increased biomechanical loading on the proximal joint from single key tapping to directional tapping.

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