INTRODUCTION

Excessive finger joint stiffness commonly occurs in individuals suffering tightness of the intrinsic muscles (e.g., the lumbral). Clinicians routinely evaluate intrinsic tightness by estimating finger joint stiffness with the Bunnell-Littler test (Bunnell, 1953). This test involves an evaluation of proximal interphalangeal (PIP) joint resistance against a manually applied force at both full extension and full flexion of the metacarpal phalangeal (MCP) joint. However, the Bunnell-Littler test is subjective and largely depends on the experience and skill of the tester. The objective of this study was to develop a quantitative approximation of the Bunnell-Littler test.

METHODS

A robot-assisted testing apparatus (Figure 1) was constructed to collect passive PIP joint torque-angle data of the index finger for extended (0°) and flexed (60°) MCP joint positions. A low payload (3 kg) industrial robotic arm (KR 3, KUKA Robotics Corporation, Augsburg, Germany) induced cyclic motion of the PIP joint, and a miniature 6-DOF force/torque transducer (Nano17, ATI Industrial Automation, NC, USA) attached to the end-effector of the robot arm measured the passive PIP joint torque. A thermoplastic splint maintained a functionally neutral wrist angle of 15° extension. A lockable linkage with a finger clamp was mounted on the splint to prescribe the desired MCP joint angles.

Six male subjects aged 28 ± 4 years (mean ± SD) without diagnosed intrinsic muscle tightness participated in this study with IRB approval. Each subject was tested once at MCP extension and flexion in a random order. The angular motion was applied to the PIP joint in a cyclic manner between full extension (0°) and 90° of flexion at 7° per second. Each trial consisted of twenty flexion/extension cycles. Throughout testing, the subject was instructed to remain relaxed and offer no voluntary resistance to the induced motion.

For each trial, the first ten cycles of torque-angle data were considered preconditioning, and the last ten cycles were averaged. The equilibrium angle of the PIP joint was determined by the zero torque intercept of the flexion curve. PIP joint stiffness was...
calculated as the slope of the induced flexion curve in a 20° window starting from the equilibrium angle (Figure 2). Paired t-tests were performed for the statistical analyses with a significance level of $\alpha = 0.05$.

RESULTS AND DISCUSSION

The averaged torque-angle relationship of the six subjects is shown in Figure 2. The results include induced flexion and extension curves at each MCP joint position. The curves at both MCP positions show distinct hysteresis. The equilibrium angle changed significantly from 52.6° ± 6.9° with the MCP joint extended at 0° to 29.4° ± 4.0° with the MCP joint flexed at 60° ($p < 0.001$). This may be due to passive tightening of the PIP joint extensors as the MCP joint assumes a flexed position.

The PIP joint showed a significant increase in stiffness from 0.40 ± 0.11 N-mm/degree with the MCP joint flexed at 60° to 0.74 ± 0.23 N-mm/degree with the MCP joint extended at 0° ($p < 0.01$). This increase (85%) is most likely due to a passive tightening of the intrinsic muscles as the MCP assumes an extended position, because passive tightening of the intrinsic muscles provides an additional PIP extension torque due to their attachment to the extensor hood via the lateral bands (Figure 3).

Our results support the underlying theory behind the Bunnell-Littler test. In future studies, we will compare PIP joint stiffness between asymptomatic hands and hands with intrinsic muscle tightness. We expect to quantify a much higher elevation in PIP joint stiffness when the MCP joint changes from flexion to extension for hands with intrinsic tightness. Additional studies will examine the effectiveness of surgical procedures of intrinsic muscle release.

SUMMARY

We have successfully developed a quantitative measure of PIP joint stiffness and framed it within a clinical context. PIP joint stiffness is dependant on the MCP joint angle, supporting the regulation role of the intrinsic muscles on PIP joint stiffness. Our method of quantifying finger joint stiffness has the potential to accurately evaluate the level of intrinsic muscle tightness.

REFERENCES


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