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A novel technique of quantifying first metatarsophalangeal (1st MPJ) joint stiffness

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The first metatarsophalangeal joint (1st MPJ) mobility is usually described by (i) range of motion in degrees (°) or (ii) stiffness based on an experienced tester's subjective feel, ie. hypermobile, normal or stiff. Approximately 65° of 1st MPJ dorsiflexion is required for normal effective walking [1]. Visual estimation of 1st MPJ range of motion is often used in current practice [2], reflecting the absence of a reliable and practical method for clinicians to quantify 1st MPJ stiffness. This study presents a novel technique to measure joint stiffness using a tactile pressure sensing system (Figure 1A) together with simple video analysis.

To illustrate the method, data were collected on one female flat-footed subject with posterior tibial tendon dysfunction (age 25 yr, body mass index 20.6 kg/m^2). The moment arm was measured from the tuberosity of the first metatarsal head to just beneath the tuberosity of the 1st distal phalanx (Figure 1B). A qualified podiatrist moved the 1st MPJ of the subject through its full range of motion before data collection. For each trial, joint movement is paused briefly at 3 interval points between the resting and maximally dorsiflexed position. At each interval point, the corresponding force applied was measured using a tactile pressure sensing system (Figure 1C). The procedures were recorded by a synchronised webcam such that the angular displacement of the 1st MPJ can be quantified using video analysis. A total of 3 trials were taken, resulting in nine sets of data points to plot a torque-angular displacement graph (Figure 2). The joint stiffness was then calculated as the slope of the line of best fit as 3.8 Nmm/deg.

Figure 1 A. Finger sleeve with pressure pad (circled) on tip of thumb to measure force applied to move the 1st MPJ. **B.** Moment arm (length of proximal phalanx) from joint fulcrum to point of force application. **C.** Displacement force applied to proximal phalanx, dorsiflexing 1st MPJ through its range of motion.

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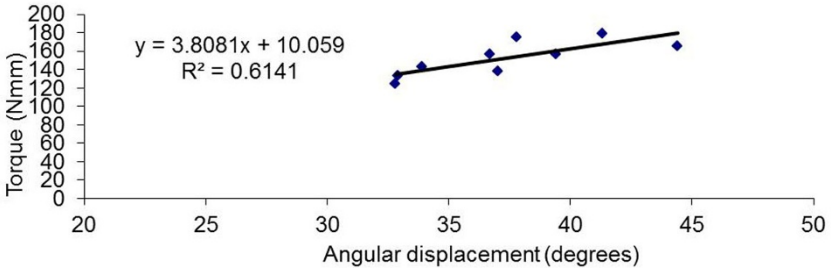

Figure 2 Plot of torque (Nmm) against angular displacement (degrees) of the 1st MPJ to determine joint stiffness from the slope.

The R^2 indicates that 61% of variability can be explained by this model.

The proposed method of quantifying 1st MPJ stiffness is potentially useful for measuring small joint stiffness in clinical practice. Quantified joint stiffness provides greater accuracy to facilitate clinicians in their diagnoses and prescription of treatment.

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