INTRODUCTION

More than 6.5 million stroke survivors currently reside in the U.S. [1]. Many stroke survivors suffer from disability in the hands and arms [2]. Loss of hand grip function limits stroke survivors’ ability to grasp and manipulate objects required by everyday activities. To grasp an object successfully, a person adapts phalanx force magnitudes and trajectories (phalanx force vector direction relative to the direction normal to the object surface) [3] to an object’s characteristics (e.g., weight, coefficient of friction (COF)) using anticipatory control as well as feedback control via sensory feedback [4]. Specifically, to maintain stable contact with a grasped object (i.e. object not slipping against the finger), phalanx force should not be deviated from the normal direction more than an angle equal to the arctangent of COF [5]. Many stroke survivors exhibit reduced tactile sensation in the fingers [6]. This reduced sensation may diminish their feedback control and cause altered grip (reduced phalanx force magnitude and misdirected phalanx force trajectories). This excessive phalanx force angular deviation for stroke survivors can lead to ineffective gripping and object slippage from the hand.

Knowledge regarding stroke survivors’ altered grip is sparse for power grip, even though power grip is often required for everyday tasks. In addition, how sensory deficit plays a role in stroke survivors’ altered phalanx force magnitudes and force trajectories has not been studied. The first objective of this study was to quantify the extent of altered phalanx force magnitudes and trajectories during power grip for people with stroke compared to age-matched neurologically-intact control subjects. The second objective was to determine if such altered power grip is severer with sensory deficit than without sensory deficit among stroke survivors with similar levels of motor deficit.

METHODS

Seven chronic stroke survivors with sensory deficit (mean age ±SD = 62±14 years), 5 chronic stroke survivors without sensory deficit (64±11 years), and 6 age-matched healthy control subjects (61±16 years) participated. Mean motor impairment, quantified by the Chedoke-McMaster Stoke Assessment [7], was stage 4 for both stroke groups.

Subjects performed power grip with maximum and 50% of perceived maximum efforts on a custom-made grip dynamometer (Fig. 1). The grip dynamometer had a rubber surface (COF with finger skin = 0.9 [8]). Normal force and proximal-distal shear force for all phalanges of the 5 fingers were recorded for 3 repetitions to compute mean phalanx normal force and trajectory. The phalanx force trajectory was quantified as the deviation of the phalanx force from the direction normal to the grip surface (arctangent of the absolute ratio of shear to normal force). Two ANOVA determined if normal force magnitude and trajectory varied significantly for subject group, grip effort, and their interaction. Finger and phalanx were blocking factors. Tukey post hoc tests evaluated differences among the 3 subject groups.

Figure 1: The grip dynamometer had 3 adjustable contact pads (a) aligned with a finger to measure each phalanx’s proximal-distal shear force (tangential to grip surface) and normal force (normal to grip surface) during power grip (b).
RESULTS

The mean normal force was 15.9 N (SE=0.8 N), 11.5 N (SE=0.8 N), and 8.6 N (SE=0.6 N) for healthy controls, stroke survivors without sensory deficit, and stroke survivors with sensory deficit, respectively (Fig. 2). Mean normal forces were significantly different among the 3 subject groups (p<.01 for ANOVA and Tukey post-hoc test for all 3 comparisons). The grip effort level and the interaction between grip effort level and subject group significantly affected normal force (p<.01).

The mean angular deviation of the phalanx force was 17.1° (SE=0.7°), 20.9° (SE=0.9°), and 25.1° (SE=1.0°) healthy controls, stroke survivors without sensory deficit, and stroke survivors with sensory deficit, respectively (Fig. 3). Mean angular deviations were significantly different among the 3 subject groups (p<.01 for ANOVA and Tukey post-hoc test for all 3 comparisons). The grip effort level and the interaction between grip effort level and subject group did not significantly affect angular deviation (p>.05).

DISCUSSION

The present study demonstrated that stroke survivors gripped with, on average, 37% reduced phalanx normal force and 35% greater phalanx force angular deviation, compared to age-matched healthy controls. More importantly, the present study demonstrated that the stroke survivors with sensory deficit gripped with, on average, 25% less normal force and 21% greater phalanx force angular deviation, compared to stroke survivors without sensory deficit. These results suggest that not only motor deficit, but also sensory deficit following stroke are responsible for impaired hand grip for stroke survivors. Stroke survivors with sensory deficit may have an increased incidence of dropping grasped objects compared to those without sensory deficit and healthy controls, not only due to a greater reduction in normal force, but also due to more altered phalanx force trajectories.

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