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KINEMATICS OF UNIMPAIRED REACH-GRASP-RELEASE DURING ROBOTIC ASSISTED REACHING

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SUMMARY
Kinematics of normal reach-to-grasp function has been investigated, described and debated. Robotic devices are increasingly being used to promote upper limb rehabilitation following neurological disease or injury such as stroke but the kinematics of reach, grasp and release using this technology is largely unknown. The study aim was to characterize the kinematics of robotic (Armeo®) assisted reaching and grasping in healthy people to compare against normal movement reaching and grasping as presented in the literature. Grip aperture scaling and time to maximum grip aperture in six healthy individuals were investigated during Armeo® reach-grasp-release tasks. The results show that the Armeo® did not interfere with 'normal' movement strategies during reach-to-grasp tasks.

INTRODUCTION
Reach-to-grasp involves two phases; 1) transportation of the hand from a start position to a location close to an object, and 2) grasp formation where shaping of the hand occurs to match the target objects dimensions to allow successful grasp [1], [2]. Kinematics of normal and impaired (stroke) reach-to-grasp has been explored [1]-[3]. As stroke rehabilitation evolves, the use of technologies, such as robotics and electrical stimulation to support task specific, intensive upper limb retraining is becoming clinically more accepted [4], [5]. To design effective systems, it is important to understand the kinematics of reach-to-grasp in both healthy and neurologically impaired populations. Knowledge of 'normal' kinematics will enable systems to be designed to mimic normal movement strategies and measure whether using these technologies with patients promotes a more normal movement. The kinematics of shoulder and elbow movement during robotic assisted reach-to-grasp in stroke patients has been explored [6], but grasp and release kinematics during robotic assisted reach-to-grasp tasks are mostly unknown in healthy and stroke populations.

The kinematics of normal reach-to-grasp varies depending on the target object's dimensions, reaching speed and distance from the starting position of the hand [2]. Although there is debate about whether the transport and grasp phases are temporally and spatially coordinated [7], it has been proposed that both components evolve in parallel [2] and general basic movement patterns or strategies can be described. As reaching progresses toward an object, the grip aperture exceeds the object size (typically at two-thirds movement duration) before closing to grasp it [1], [2]. The objective of the study was to assess whether the Armeo® interferes with 'normal' movement patterns during reach-to-grasp tasks.

METHODS
Six unimpaired individuals over 50 years of age (mean age = 62, range = 50 to 76; 4 female, 2 male; 5 right- and 1 left-hand dominant) were recruited into the study following informed consent (Ethics Number: SOHS 08-004). During experiments, participants were seated at an adjustable table, feet placed flat on the floor, with Armeo® (HOCOMA, Zurich) fitted and adjusted to the participant's dominant arm. In the starting position, the shoulder was in a neutral adducted position with 0° flexion/extension, elbow with approximately 90° flexion and forearm pronated with fingertips resting at the table edge. Participants were instructed to reach forward 20cm at a normal reaching speed, grasp an 80mm diameter touch sensitive cylinder, move it proximally by 10cm, place it down on the table, release it and move the hand back 10cm to the start position. The task was then repeated three times.

Data was generated by: the Armeo® (shoulder and elbow movement), a touch-sensitive cylinder (to detect initial cylinder contact and release) and the Vicon T-Series 12-camera movement analysis system (6 x T160 and 6 x T40 cameras), sampling at 100Hz. To generate kinematic data of the wrist and hand, 26 x 3mm hemispherical passive reflective markers were attached to the dorsum of the wrist according to a standardized protocol [8]. Marker trajectories and 3D co-ordinates were then generated and joint angles were calculated using a validated kinematic measurement technique [8] using MATLAB™ (Math Works, Inc., Natick, MA). In addition, grip aperture scaling and kinematic sequencing were generated from the resultant joint angle data. All data were synchronized to the initial movement of the wrist and normalized to 100% of the movement cycle.

RESULTS AND DISCUSSION
Figures 1 and 2 show grip aperture scaling (index finger tip to thumb tip) and grasp/release timings during Armeo® assisted reach-to-grasp tasks for one individual (3 repeats) and six individuals (average of 3 repeats) respectively. The kinematic strategies were comparable between participants and are illustrated for a representative participant in Figure 1. During the first ~6% of task, the grip aperture decreased before rising to maximum (larger than object size) at ~35% of task during reach. The object recorded initial hand contact at ~40% of the

task as the grip aperture closes to complete the grasp at ~48% of the task. The grip aperture then remained constant as the object was transported; release started at ~67% of task, with complete object release at ~75% and maximum release apertures at ~77% of task respectively. Release apertures were shown to be greater and the release phase occurred faster than those observed during the grasping phase, perhaps reflecting reduced effort having completed the task.

Most reach-to-grasp studies present data up to object grasp. During this period, grip aperture scaling using the Armeo® is similar to normal scaling patterns as described in the literature [1]. The hand opens larger than object size as the reach phase develops, then closes to grasp the object. However, the grip aperture briefly closes at the start of transport before opening to maximum during the release phase. This feature is reported in the literature in normal reach-to-grasp tasks [9]. The time to maximum grip aperture using the Armeo® occurred at approximately ~75% of movement time and is analogous to findings for normal reach-to-grasp [1], [2].

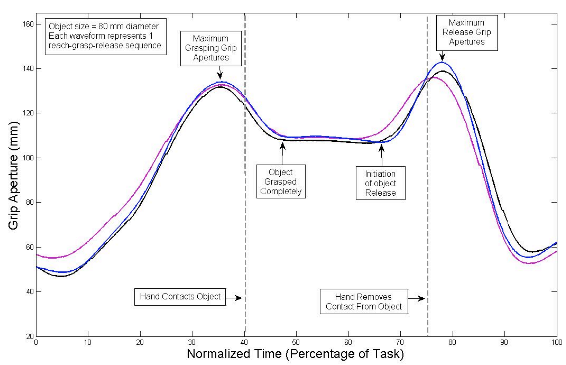

Figure 1: Representative grip aperture scaling and timing for one individual during Armeo® assisted reach-to-grasp tasks.

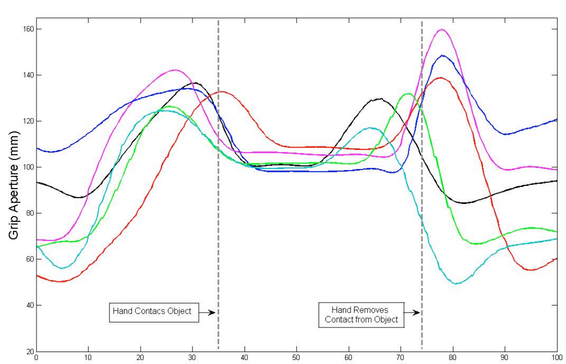

Figure 2: Averaged grip aperture scaling and timing for six individuals during Armeo® assisted reach-to-grasp tasks.

CONCLUSIONS

Armeo® assisted grip aperture scaling and time to maximum grip aperture during reach-to-grasp tasks are similar to those reported in the literature for normal, unassisted reach-to-grasp tasks. This suggests that similar movement strategies are employed in both unassisted and Armeo® assisted reach-to-grasp tasks in an unimpaired sample. Additionally, Armeo® assisted release apertures were greater and the release phase occurred faster than those of the grasping phase. In conclusion, the results of this preliminary study show that the use of the Armeo® does not affect normal movement strategies during reach-to-grasp. This indicates that the Armeo® may be a useful tool for upper limb rehabilitation following stroke.

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