Grasping Naturally Versus Grasping With a Reacher in People Without Disability: Motor Control and Muscle Activation Differences

Kinsuk K. Maitra, Katherine Philips, Martin S. Rice

KEY WORDS
• biomechanics
• electromyography
• hand strength
• motor control
• self-help devices
• task performance and analysis

OBJECTIVE. We investigated motor control and muscle activation when reaching for and grasping objects with a reacher compared with the unaided hand.

METHOD. In a repeated-measures counterbalanced design, 41 healthy participants with no previous experience using a reacher were randomly assigned to a sequence of four conditions. Movements of the wrist and fingers were recorded using a three-dimensional Qualisys camera system for assessing reach and grasp. Muscle activations from finger and arm flexors and extensors were recorded by surface electromyography.

RESULTS. Participants exhibited a smaller grasp aperture, longer reaching time, and more muscle activity when they used a reacher.

CONCLUSION. Efficient motor control, which requires both time and practice, is needed to successfully use a reacher. Clients presented with reachers without sufficient time to develop motor skills unique to reacher use may be more likely to abandon this assistive device and fail to benefit from its function.


Occupational therapists often recommend assistive devices to clients to enhance functional independence in daily life activities. A common example of an assistive device is a reacher. Although the reacher is a standard piece of adaptive equipment recommended for people with decreased grip strength or range of motion, few studies have identified the extent to which function is impaired by reacher use. For example, the grasping pattern of a reacher may differ from a hand grasp in several ways. A different set of muscles may be activated in reacher use than in a natural grasp pattern. Stability of the reacher–object interface may be compromised because of limited contact surface area between the object and the two reacher prongs. Sensory feedback from the reacher may be insufficient for adequate motor control. Object characteristics and task complexity may cause further instability. For example, grasping a round object, like a ball or apple, with a reacher could be more difficult than grasping a square object, such as a Rubik’s Cube (Seven Towns Ltd., London) or cookie box.

Although few studies reported in the literature examined the reacher as an assistive device, several studies addressed motor control issues of comparable prosthetic devices. For example, Wing and Fraser (1983) studied reaching and grasping in a young girl with a below-elbow prosthesis that had a split hook to allow for grasp. The prosthetic hand required significantly more time to perform a reach grasp task than did the hand without the device. Maruishi et al. (2004) compared brain activation location for repetitive grasp using a computer-generated virtual prosthetic...
arm without visual feedback (eyes closed condition) and with visual feedback (eyes open condition) with repetitive grasp using the natural hand under similar conditions. Researchers found that the right posterior parietal cortex (a traditional sensory-processing area) was activated in both the prosthetic and the natural hand conditions. In the prosthetic hand condition, however, the center of activation in the right posterior parietal area was shifted laterally compared with the natural hand condition. Maruishi et al. (2004) surmised that the brain can recognize the prosthetic arm as an alternative to the natural hand and can control the prosthetic arm by means of a mirror neuron system in the brain.

In a behavioral study, Gentilucci, Roy, and Stefanini (2004) found differences in motor control characteristics when reaching for and grasping objects of different sizes using a reacher compared with the unaided hand. Gentilucci et al. found that although reaching characteristics were similar, grasping characteristics were significantly different. Grasp aperture was larger, and grasp aperture velocity was slower in a reacher grasp than in a hand grasp. More important, reach and grasp were not synchronized in the reacher grasp compared with the natural grasp. Such desynchronization of reach and grasp led the researchers to believe that tool grasp may be controlled differently in the brain from natural grasp; tool grasp may be mediated by a mirror neuron system, as suggested by Maruishi et al. (2004).

Barger et al. (2000) explored whether grip strength, coordination, and hand size in older adults could affect the time required to complete an activity using a reacher. Participants used a reacher to retrieve one sock and place the sock in a laundry basket. Grip strength was measured by a dynamometer; coordination was measured by the Box and Block Test (Mathiowitz, Volland, Kashman, & Weber, 1985).

Researchers found a nonsignificant low correlation ($r = .118, p = .408$) between grip strength and the time required to complete the reacher activity. However, a significant moderate inverse correlation ($r = -.506, p < .001$) was found between coordination and time needed to complete the reacher activity. Moreover, regression analysis suggested that coordination was a significant predictor of time required to complete the reacher task (Barger et al., 2000).

The literature suggests that reach and grasp kinematics associated with a reacher grasp may be significantly different from those associated with a natural grasp. It appears that motor coordination may need to be assessed carefully before recommending reacher use. Because few studies have examined assistive devices, particularly reachers, there is a need to explore how motor control is affected in reacher versus natural grasp activities. There is also a need to study movement-related muscle activation patterns (with electromyography) to better understand the motor control issues related to reacher–grasp activities. This information is necessary for therapists to provide the most effective training in reacher use to lessen the likelihood that patients will abandon its use.

The purpose of the current study was to systematically investigate the movement characteristics and muscle activation patterns of the upper extremity when reaching for and grasping different objects with a reacher and with the unaided hand. On the basis of the literature, the following hypotheses were formulated: (1) Use of a reacher, compared with use of the hand, yields significant mean differences in kinematic parameters when participants reach for and grasp four objects of different shapes and sizes, and (2) use of a reacher, compared with use of the hand, yields significant mean differences in muscle activation patterns, as measured by net and relative muscle excitation, when participants reach for and grasp four objects of different shapes and sizes.

**Method**

**Participants**

Forty-one healthy adults ages 18 to 55 from the Toledo, Ohio, area were voluntarily recruited for the study. Inclusion criteria consisted of (1) absence of any physical or cognitive impairment, (2) right-hand dominance, and (3) normal vision with or without corrective lenses. Prescreening included (1) testing of the upper extremity for normal range of motion (ROM) and hand strength testing with a cutoff at 40 lb (Mathiowetz, 1990); (2) the Mini-Mental State Exam (MMSE; Folstein, Folstein, & McHugh, 1975), with a required score range of 26 to 30; and (3) the Edinburgh Handedness Inventory (Oldfield, 1971). All participants were required to read and sign an informed consent document approved by the University of Toledo Health Science Center Institutional Review Board for human participant research. Participants were unaware of the experimental hypotheses before the experiment. No participant could have previous experience using a reacher to ensure that the reacher task would be novel for all participants. A debriefing was provided on request after study completion.

**Study Design**

A $2 \times 2 \times 2$ repeated-measures analysis of variance (ANOVA) design was used to analyze the differences between reacher grasp and hand grasp. In this design, the grasping apparatus had two levels: the hand and the reacher. Object characteristics were defined by two factors: shape (two levels: round and square) and size (two levels: small and large). This process created four types of object characteristics: (1) small round (a golf ball), (2) large round (a baseball), (3) small square (a small Rubik’s Cube), and (4) large square (a large
Rubik’s Cube). Small round and small square objects were of equal weight; likewise, large square and large round objects were of equal weight. Such a $2 \times 2 \times 2$ design created seven within-subject effects consisting of three main effects and four interaction effects as shown in Table 1.

**Task and Apparatus**

The study took place at the Collier Building Motor Control Laboratory of the Occupational Therapy Department, University of Toledo. The participants, in individual sessions, sat in a chair facing a table with hips and knees at 90° and trunk in midline. In the starting position for the natural grasp, participants placed their right hand with index and thumb in a pinch position on a red disk switch (DS) located on the edge of the table in the sagittal plane directly in front of their right arm. From this point, they reached for and grasped an object located 15 cm forward without bending their trunk and then placed the object on a cross mark 20 cm to the left (Figure 1a). In reaching conditions, the task and setup were similar to the hand conditions (i.e., natural grasp) except that the object was moved farther forward so that the object remained 15 cm from the endpoint of the reacher (Figure 1b). As stated earlier, four different objects were used for grasping: a golf ball (1.67 in. in diameter), a baseball (3 in. in diameter), a small Rubik’s Cube (1.5 x 1.5 in.), and a large Rubik’s Cube (2.25 x 2.25 in.).

**Procedure**

In a repeated-measures counterbalanced design, the participants were randomly assigned to a sequence of four conditions:

1. **Condition A**: reaching–grasping a golf ball
2. **Condition B**: reaching–grasping a baseball
3. **Condition C**: reaching–grasping a small Rubik’s Cube
4. **Condition D**: reaching–grasping a large Rubik’s Cube.

The possible sequences of tasks were ABCD, BCDA, CDAB, and DABC. Before the first trial, the participants were instructed to keep their trunks stable with their backs against the chair and their feet flat on the floor throughout all trials.

**Table 1. Distribution of Within-Subject Factors and the Interaction Factors as a Result of 2 × 2 × 2 Analysis of Variance Design**

<table>
<thead>
<tr>
<th>Main Factor 1</th>
<th>Main Factor 2</th>
<th>Main Factor 3</th>
<th>Interaction 1</th>
<th>Interaction 2</th>
<th>Interaction 3</th>
<th>Interaction 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grasp</td>
<td>Size</td>
<td>Shape</td>
<td>Grasp × Size</td>
<td>Grasp × Shape</td>
<td>Size × Shape</td>
<td>Grasp × Size × Shape</td>
</tr>
</tbody>
</table>

When the researcher stated “begin,” participants reached from the DS toward the object with either reacher or hand, grasped the object, and placed the object as fast as they could on the cross-mark position without compromising accuracy of placement. After placing the object, participants returned their hands to the DS to end the specific trial. The study included 12 trials each using the reacher and the natural grasp (3 trials for each object).

**Instrumentation**

A three-dimensional movement recording system based on infrared technology (Qualisys Version 3.0; Qualisys AB, Gothenburg, Sweden) was used to record arm, hand, and finger movements at 120 Hz. This system was calibrated before the experiments and was found to be reliable and accurate for dynamic motion capture measurements within 1 mm (Qualisys AB, 2006). Four infrared markers were located on the right arm and hand, and five infrared reflectors were located on the reacher. The first infrared reflector was attached to the thumbnail, the second reflector was attached to the index fingernail, and the third reflector was...
attached to the radial side of the forearm 1 cm proximal to the wrist. The marker movement on the thumb and index finger was used to analyze grasp; the sensor placed near the wrist was used to analyze reaching. The fourth reflector was placed on the acromioclavicular joint to check for steadiness of the shoulder. Another reflector was attached to the object to trace the trajectories of the object’s movement. During the reaching conditions, five additional infrared reflectors were placed on the prongs of the reacher. The three-dimensional (C3D) motion sensor data were tracked and recorded by four cameras and then labeled for identification and stored in the C3D format for offline analyses.

For noninvasive surface electromyography (EMG), we used the Bagnoli EMG system (Delsys Inc., Boston, MA). The bipolar EMG electrodes were placed over the biceps and triceps to quantify muscular involvement in reaching. For the grasping component, the EMG electrodes were placed on the long finger flexors and extensors, as well as on the pollicis muscles, which included the flexor digitorum profundus, flexor digitorum superficialis, flexor pollicis longus, and adductor pollicis. Electrodes were placed close to the motor end plates following the estimation used by Cram, Kasman, and Holtz (1998). The analog EMG signal was processed by means of an EMG preamplifier at a gain of 1,000 with a common mode rejection ratio of 90 dB. The EMG signal was digitized online at a sample rate of 1200 Hz using a data acquisition card (PCIDAS–6402/16, Measurement Computing, Inc.) and was stored along with movement data in C3D format for offline analysis. Lifting of the hand from the red DS acted as a trigger to initiate data collection in 0.5 s (60 frames) pretrigger mode.

Data Reduction and Analysis

The offline movement and EMG data were processed by a custom routine built using the Visual 3D software (C-Motion Analysis, Inc., Rockville, MD). For the movement data, the routine first filtered the data using a second-order Butterworth filter with forward and backward passes at a low-pass cutoff frequency of 6 Hz (Nilsen, Kaminski, & Gordon, 2003). If there were missing data, the routine then interpolated the data up to 10 points using a linear spline. Trials with missing data of more than 10 points were not analyzed. Movements were then digitally differentiated to obtain the velocities of the movements. Movement onset and offset were determined by using a commonly used criterion velocity of 0.025 m/s (Glover & Dixon, 2002). The wrist marker was used to determine the onset and offset of reaching, whereas the thumb marker was used to determine the onset and offset of grasping (the thumb tends to stay fairly stable during the movement; Glover & Dixon, 2002; Wing & Fraser, 1983).

Dependent variables for the reach task extracted were as follows:

1. **Peak velocity of reach.** Peak velocity in a velocity profile of a movement is an indicator of the force that movement requires; the faster the movement is, the greater the force the system requires to generate movement (Flash & Hogan, 1985; Trombly & Wu, 1999). Peak velocity of reach was computed as meters per second (m/s).

2. **Reach time.** Reach time (in seconds) was measured using onset–offset criteria mentioned previously to estimate speed of movement.

3. **Percentage of time to reach peak velocity (%)**. An efficient movement is usually characterized by a single bell-shaped velocity profile. If the shape of the bell is symmetrical, it means that the movement is preprogrammed and no corrections are needed at the end. However, as accuracy demands increase for successful completion of the movement, more visual or other feedback is necessary. This results in a velocity profile that becomes skewed at the deceleration phase. Normally, the peak of a velocity profile of a learned and practiced movement is between 30% and 50% of the total movement (Bullock & Grossberg, 1988; Nagasaki, 1989). Thus, a left shift of peak velocity means a right skewed deceleration profile, indicating a guided strategy. Conversely, a right shift of peak velocity means either a more ballistic strategy that requires no guidance (aimless fast pointing) or a highly learned strategy (fast piano playing; Trombly & Wu, 1999). Percentage of total reaching movement where the peak velocity occurred was computed.

Further discussion of the utility of these variables in analyzing movements can be found in Trombly and Wu (1999). Following similar arguments as detailed previously, variables for the grasp task extracted from the finger data were as follows:

1. **Maximal grasp aperture** (distance between thumb and index finger in meters throughout the reach and grasp task)

2. **Peak velocity of grasp aperture (m/s)**

3. **Time to reach maximal grasp aperture.**

**Electromyography**

Offline analyses included removal of linear trend and artifacts from the EMG data by using a 10th-order digital Butterworth band-pass filtering (cutoff frequency = 40–400 Hz) and the calculation of root-mean-square (RMS) value from the filtered EMG data. The mean RMS value was then calculated by averaging the value from three trials per condition. A baseline RMS value of each EMG signal was obtained by calculating the mean value of resting EMG for 200 ms. Each EMG signal was standardized in terms of standardized.
The American Journal of Occupational Therapy

Figure 2. Scheme for electromyographic analysis.


Note. EMG = electromyography; RMS = root mean square; SNE = standardized net excitation; RE = relative excitation. Nos. 1–5 indicate five recorded electromyographs from five muscles (i.e., biceps, triceps, wrist flexors, wrist extensors, and pollicis).

net excitation of a muscle (SNE\textsubscript{i}, \(i = 1–5\)) by subtracting the active RMS from its baseline RMS value and then normalizing the value with the baseline RMS value. The summation of all the SNE\textsubscript{i} from all five recorded muscles constituted the SNE. The relative contribution (RE\textsubscript{i}, \(i = 1–5\)) of an individual muscle to the SNE was calculated by dividing SNE\textsubscript{i} value by the SNE value. SNE and individual RE variables were subjected to a \(2 \times 2 \times 2\) within-subject repeated-measures ANOVA. The aforementioned analyses of standardized or global activation of EMG (Figure 2), although new, are now increasingly used to estimate global muscle activation for a task (Hwang et al., 2005).

**Statistical Analysis of Motion Data**

All of the kinematic variables were averaged over repeated trials for a condition and the mean values were subjected to ANOVA analysis using the SPSS 13.0 statistical software package (SPSS, Inc., Chicago).

The experimental design accounts for three within-subject factors for grasp and reach (type of grasp: natural vs. reacher; object size: small vs. large; and shape: round vs. square). Separate \(2 \times 2 \times 2\) within-subject repeated-measures ANOVAs were conducted on the mean values of the analyzed reaching–grasping parameters and associated EMG parameters.
Results

Grasp Component

Average values (mean [M] and standard deviation [SD]) of all kinematic parameters of grasp are listed in Table 2.

Maximal Grasp Aperture

A within-subjects 2 x 2 x 2 repeated-measures ANOVA revealed that mean maximal grasp aperture was significantly larger (main effect of grasp) when reaching naturally (M = 0.074 m, standard error [SE] = .003) than when reaching with the reacher (M = 0.023 m, SE = .001, F[1, 41] = 259.752, p = .0001, η² = .864). Mean maximal grasp aperture was significantly larger (main effect of size) when reaching for the larger object (M = 0.054 m, SE = .002) than when reaching for the smaller object (M = 0.042 m, SE = .002, F[1, 41] = 85.073, p = .0001, η² = .675). Scaling of mean maximal grasp aperture, however, was evident only in hand grasp. In reacher grasp, the mean maximal grasp aperture was not sensitive to size or shape. As expected from the mean, a significant interaction was yielded between the main factor of grasp and size (F[1, 41] = 68.439, p = .0001, η² = .625). Main effects of shape and other interactions were not significant.

Peak Velocity of Finger Aperture. Peak velocity of finger aperture was significantly increased (main effect of grasp) when reaching naturally (M = .644 m/s, SE = .022) than when reaching with the assistive device (M = .312 m/s, SE = .023, F[1, 41] = 107.537, p = .0001, η² = .724). Main effects of size and shape were not significant. Also, no significant interactions were yielded between the three main effects.

Time to Achieve Maximal Velocity. Time to reach peak velocity of maximal finger aperture was significantly longer when reaching naturally (M = 0.143 s, SE = .01) than when reaching with the assistive device (M = 0.106 s, SE = .01, F[1, 41] = 6.723, p = .013, η² = .141). Significant difference was also found in the main effect of shape, although with a small effect size (F[1, 41] = 7.044, p = .011, η² = .147). Thus, time to reach peak velocity was significantly shorter when reaching for a round object (M = 0.109 s, SE = .007) than when reaching for a square object (M = 0.141 s, SE = .011). Main effect of size was not significant. Also, no significant interactions were yielded between the three main effects.

Reach Component

Average values (M and SD) of all kinematic parameters of reach are listed in Table 3.

Reach Time. Reach time was significantly shorter (main effect of grasp) when reaching naturally (M = 0.435 s, SE = .008) than when reaching with the reacher (M = 0.546 s, SE = .013, F[1, 41] = 88.083, p = .0001, η² = .682). Main effects of size and shape were not significant. Also, no significant interactions were found between the three main effects.

Peak Velocity of Reach. Peak velocity of reach was increased significantly when using the hand (M = 0.441 m/s, SE = .017) compared with the reacher (M = 0.289 m/s, SE = .011, F[1, 41] = 138.422, p = .0001, η² = .771). The interaction between type of reach (natural or assistive device) and size (large or small) also yielded significance, although with a small effect size (F[1, 41] = 6.612, p = .017, η² = .131). This parameter was not affected by other factors or the interactions between them. Thus, tool difference (i.e., hand vs. reacher) and not the object characteristics affected the reaching pattern.

Percentage of Movement Time to Reach Maximum Reach Velocity. Acceleration time was significantly different when reaching naturally (M = 0.492 [49%], SE = .008) than when reaching with the assistive device (M = 0.404 [40%], SE = .007, F[1, 41] = 108.557, p = .0001, η² = .731). Thus, in hand grasp, acceleration and deceleration were symmetrical and dome shaped, and each one required approximately 50% of the movement time. In reacher grasp, however, the deceleration task took more time (~60%) than the acceleration task (~40%). Main effects of size and shape were not significant; however, a significant interaction was observed between the type of reach (natural or reacher), shape (round or square), and size, although the effect size was small (F[1, 41] = 5.573, p = .023, η² = .122).

Table 2. Average Values of Grasping Parameters for Natural Grasp and for Grasping With Reachers for Four Different Objects Consisting of Two Sizes and Two Shapes (N = 41)

<table>
<thead>
<tr>
<th></th>
<th>Hand</th>
<th></th>
<th>Reacher</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Large</td>
<td>Small</td>
<td>Round</td>
</tr>
<tr>
<td>Maximum grasp aperture (m)</td>
<td>.066 (.023)</td>
<td>.063 (.021)</td>
<td>.062 (.025)</td>
</tr>
<tr>
<td>Peak velocity during grasp (m/s²)</td>
<td>.648 (.195)</td>
<td>.650 (.154)</td>
<td>.660 (.284)</td>
</tr>
<tr>
<td>Time taken to reach peak velocity of maximum grasp (s)</td>
<td>.109 (.049)</td>
<td>.113 (.092)</td>
<td>.108 (.184)</td>
</tr>
</tbody>
</table>

Note. M = mean, SD = standard deviation, m = meters, s = seconds.

Downloaded From: http://ajot.aota.org/ on 10/13/2018 Terms of Use: http://AOTA.org/terms
Table 3. Average Values of Reaching Parameters for Natural Reach and for Reaching With Reachers for Four Different Objects Consisting of Two Sizes and Two Shapes (N = 41)

<table>
<thead>
<tr>
<th></th>
<th>Hand</th>
<th></th>
<th></th>
<th>Hand</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Large</td>
<td>Small</td>
<td>Large</td>
<td>Small</td>
<td>Large</td>
<td>Small</td>
</tr>
<tr>
<td></td>
<td>M (SD)</td>
<td>M (SD)</td>
<td>M (SD)</td>
<td>M (SD)</td>
<td>M (SD)</td>
<td>M (SD)</td>
</tr>
<tr>
<td>Reaching time (s)</td>
<td>.425 (.069)</td>
<td>.444 (.076)</td>
<td>.426 (.073)</td>
<td>.447 (.078)</td>
<td>.546 (.129)</td>
<td>.549 (.111)</td>
</tr>
<tr>
<td>Peak velocity during reach (m/s)</td>
<td>.435 (.119)</td>
<td>.452 (.121)</td>
<td>.437 (.116)</td>
<td>.441 (.122)</td>
<td>.284 (.088)</td>
<td>.272 (.086)</td>
</tr>
<tr>
<td>Percentage of the reaching time taken to reach peak velocity</td>
<td>51.0 (7.8)</td>
<td>48.9 (6.6)</td>
<td>49.0 (6.1)</td>
<td>47.9 (7.6)</td>
<td>39.1 (7.0)</td>
<td>40.9 (9.7)</td>
</tr>
</tbody>
</table>

Note. M = mean, SD = standard deviation, m = meters, s = seconds.

Electromyographic Results

Reaching and grasping objects either with the hand or with the reacher was achieved by a concerted effort of muscular activity involving many muscles. We recorded two muscles (biceps and triceps) for reaching and three muscles (wrist flexors, wrist extensors, and pollicis) for grasping. SNE of all muscles and RE of individual muscles were computed from the rectified, root-mean-squared filtered data of EMG (Figure 2). Average (M and SD) EMG parameters are given in Table 4.

Standardized Net Excitation. SNE was found to be significantly different for the main effect of grasp ($F[1, 41] = 7.310, p = .010, \eta^2 = .151$). In other words, the standardized or global electromyographic activity was significantly less when reaching naturally ($M = 8.763, SE = .363$) than when reaching with a reacher ($M = 10.217, SE = .555$). The SNE was also significantly more when reaching for large objects ($M = 10.117, SE = .555$) than for small objects ($M = 8.863, SE = .373, F[1, 41] = 19.992, p = .0001, \eta^2 = .328$). Main factor of shape was not significant. No significant interactions were observed between any of the main factors.

Relative Excitation of Muscles

Reaching. Relative excitation of the biceps reached significance for the main factor of size ($F[1, 41] = 8.789, p = .005, \eta^2 = .180$). In other words, contribution of the biceps to the task was relatively higher when reaching for small-sized objects ($M = 31.168\%, SE = 2.206$) than when reaching for large-sized objects ($M = 27.183\%, SE = 1.880$). The main factor of shape did not yield significance for biceps activation. Although relative excitation of the biceps was higher when reaching with the reacher ($M = 30.731\%, SE = 2.592$) than when reaching naturally ($M = 27.620\%, SE = 1.541$), the ANOVA of this main factor did not reach significance ($F[1, 41] = 3.039, p = .089, \eta^2 = .071$). Three significant interactions were yielded for relative excitation of biceps: one between the main factors of reaching (naturally or with reacher) and size (large or small) ($F[1, 41] = 5.570, p = .023, \eta^2 = .122$); a second between the main factors of reaching (naturally or with reacher) and shape (round or square) ($F[1, 41] = 6.583, p = .014, \eta^2 = .141$); and a third between the interactions of all three main factors of reach, size, and shape ($F[1, 41] = 5.714, p = .022, \eta^2 = .122$).

Table 4. Average Values of EMG Parameters for Natural Grasp and for Grasping With Reachers for Four Different Objects Consisting of Two Sizes and Two Shapes (N = 41)

<table>
<thead>
<tr>
<th></th>
<th>Hand</th>
<th></th>
<th></th>
<th>Hand</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Large</td>
<td>Small</td>
<td>Large</td>
<td>Small</td>
<td>Large</td>
<td>Small</td>
</tr>
<tr>
<td></td>
<td>M (SD)</td>
<td>M (SD)</td>
<td>M (SD)</td>
<td>M (SD)</td>
<td>M (SD)</td>
<td>M (SD)</td>
</tr>
</tbody>
</table>

Note. M = mean, SD = standard deviation.
The relative excitation of the triceps was significantly higher when reaching for small objects ($M = 13.98\%$, $SE = 1.865$) than when reaching for large objects ($M = 12.42\%$, $SE = 1.52$, $F[1, 41] = 7.939$, $p = 0.007$, $\eta^2 = .162$). The other main factors did not yield significance. One significant interaction was observed between the main factor of reach (reaching naturally or reaching with reacher) and the main factor of shape (round or square; $F[1, 41] = 5.709$, $p = 0.022$, $\eta^2 = .122$).

**Grasping.** For grasping, the relative contribution from the wrist flexors was not significantly different when reaching naturally than when reaching with the reacher. Excitation of the wrist flexors, however, was significantly higher when reaching for large objects ($M = 16.495\%$, $SE = 1.442$) than when reaching for small objects ($M = 15.17\%$, $SE = 1.23$, $F[1, 41] = 10.384$, $p = .002$, $\eta^2 = .202$). No other main factors or interactions yielded significance.

The relative contribution from the wrist extensors was significantly lower when reaching naturally ($M = 22.15\%$, $SE = 1.798$) than when reaching with the assistive device ($M = 25.88\%$, $SE = 2.194$, $F[1, 41] = 5.414$, $p = .025$, $\eta^2 = .117$). Similar to wrist flexor activation, relative contributions from the wrist extensors only yielded significance in the main factor of size. In other words, excitation of the wrist extensors was significantly higher when reaching for large objects ($M = 24.91\%$, $SE = 1.94$) than when reaching for small objects ($M = 22.11\%$, $SE = 1.78$, $F[1, 41] = 7.420$, $p = .001$, $\eta^2 = .153$).

Interestingly, the relative contributions from the pollicis were only significant for the main factor of grasp. In other words, the contribution from the pollicis was significantly larger when reaching naturally ($M = 20.96\%$, $SE = 2.76$) than when reaching with the reacher ($M = 14.62\%$, $SE = 2.47$, $F[1, 26] = 11.595$, $p = .002$, $\eta^2 = .308$).

**Discussion**

The purpose of this study was to investigate whether motor control (Hypothesis 1) and muscular characteristics (Hypothesis 2) were different when reaching for and grasping an object with the hand than when using a common assistive device, a reacher. The study investigated the issue by using four objects of different sizes and shapes to reach and grasp.

Significant differences in several kinematic parameters were observed when completing reaching and grasping movements with a reacher than with the hand. Thus, results support the first hypothesis that motor control characteristics are different in a reacher grasp than in a natural grasp. Natural grasp is characterized by faster reach and larger grasp aperture with higher peak velocity. In comparison, a reacher grasp is characterized by a smaller grasp aperture and shorter acceleration profile. In addition, in natural grasp, the peak velocity of reach occurred at 49% of the movement indicating that in natural grasp, acceleration and deceleration time were almost equal. By contrast, peak velocity of reach in a reacher grasp occurred at 40% of the movement. This means that a reacher grasp has longer deceleration time in reaching. In other words, the upper extremity moves more slowly in the latter half of the movement as the reacher approaches the object to be retrieved.

The reach portion of a reacher grasp was not influenced by size or shape; the grasp component, however, was positively influenced by size but not shape. The smaller grasp aperture and the shorter acceleration of a reacher grasp indicated a left shift of the velocity profile and, therefore, a longer deceleration. Thus, it appears that when participants reached with the assistive device, they were more cautious and slower in the latter half of their movement when reaching for grasping objects, possibly because of the high demands resulting from the unstable reacher–object interface. Such slow, cautious deceleration also meant that participants were not receiving sufficient kinesthetic information from the reacher and had to rely on visual feedback to negotiate objects (Gentilucci, 2002). Thus, results indicate that grasping with a reacher was not efficient and likely involved a pattern of learning for a novel task (Jaennerod, 1988; Smeets & Brenner, 1999). Similarly, Gentilucci (2002) suggested that slow deceleration with a reacher could be caused by a lack of sensory information coming from the reacher prongs when the prongs were in contact with objects. This finding has particular importance for patients with proprioceptive and sensory deficits who must rely on visual feedback to achieve sufficient reacher control.

Muscle activation pattern yielded an interesting and important insight into the central control of a reacher grasp versus a hand grasp. Combined muscular activations (as measured by standardized net excitation) were less in a natural grasp than in a reacher grasp; combined muscular activations were also sensitive to size, that is, more activation occurred when reaching for larger objects. Individually, biceps and triceps activations were higher with smaller objects than with larger objects. Wrist flexor and extensor activations, however, were higher with larger objects. Contributions from the pollicis were higher in hand grasp. From these varied activation patterns, it appears that higher activation of the biceps and triceps for smaller sized objects may be related to the stability of the arm–object interface. Higher activation of flexors and extensors for larger sized objects may be related to the force requirement of the task.
However, in addition to the size and shape effect at the individual muscle activation level, there was not much difference between a reacher grasp and a hand grasp. Therefore, it is possible that the brain begins with a similar program of muscle activation for both hand and reacher grasps, assuming task equivalency, and subsequently modifies the movement program at the effector level as the stability of object–grasp interface is recalculated with available feedback. Thus, results indicate that learning a novel task happens at the central (i.e., central nervous system) and the effector (i.e., peripheral nervous system) levels (Bapi, Doya, & Harner, 1998). In other words, results suggest that with practice, the brain may begin to think of the reacher as a useful alternative to hand grasp.

The results of the current study showed some differences from those of a similar study conducted by Gentilucci et al. (2004). We found maximal grasp aperture and peak velocity of finger aperture to be larger in the hand grasp than the reacher grasp; Gentilucci et al. (2004) found opposite results. Reasons for these differences may be accounted for by the sample size or the type of objects used. The Gentilucci et al. (2004) study used 8 participants, whereas the current study admitted 41 participants; an increase in the number of participants could have accounted for different results. The objects used in the studies also differed. The current study used objects of different sizes and shapes, whereas the Gentilucci et al. (2004) study did not address different shapes.

It is now well recognized that grasping is a complex process that is characterized by two phases: an earlier opening phase and a later closing phase. In the opening phase, the fingers are shaped according to the physical properties of the object (i.e., size and shape) while the arm is in flight. The wrist then orients the arm toward the object for a smooth approach to contact. A second closing phase initiates when fingers flex around the object for a stable grasp (Gentilucci, 2002; Jeannerod, 1988). Varying the object properties would influence the reaching and grasping pattern. Because the reacher has only two prongs and limited shaping, orientating, and flexing capabilities, it would be worthwhile to examine how a variety of object characteristics influence reacher function.

The current study’s results were similar to those of the Gentilucci et al. (2004) study with regard to acceleration time of reach; both studies found that acceleration time with the reacher was significantly quicker than with the hand. Therefore, it appears that the initial opening phase was quicker with the reacher in an attempt to preshape its prongs to the object characteristics; however, the closing phase was longer because the brain was still attempting to calculate a pattern for stable grasp.

Implications for Occupational Therapy

In summary, motor control and muscle activation characteristics are significantly different when reaching to retrieve an object with a reacher than when reaching with the natural hand. The study points to the fact that people without disability also undergo a period of learning when they use a reacher for the first time to retrieve objects of different shapes and sizes. Although not tested in the current study, it may be assumed that people with disability may experience greater difficulty learning to use a reacher than people without disability. Findings from this study suggest that some level of motor learning and motor planning is needed to accomplish tasks using a reacher in nonclinical populations. Physical factors (such as decreased grip strength, range of motion, and motor coordination) and cognitive factors (such as impaired perception and processing speed) could potentially interfere with successful and sustained reacher use in specific clinical populations.

The results of this study support the need for occupational therapists to understand differences in reach and grasp parameters between using the natural hand and using a reacher. If an occupational therapist recommends an assistive device, such as a reacher, the therapist must first understand whether the patient has the ability to use the device with objects of various sizes and shapes encountered in everyday occupations. The results of previous studies suggest that the brain initially considers the reacher grasp as a novel task. A sufficient amount of training and practice is needed before patients will develop the motor learning and control needed to master reacher use in various activities of daily living (ADLs). Thus, it is important that therapists invest adequate assistive device training time with patients to help them develop the motor coordination and skill needed for desired ADLs. Patients who are given reachers without sufficient training and supervised practice may be more likely to abandon the reacher if, in their initial use, they do not have the motor skills to negotiate the reacher–object interface and do not understand that such motor skills can often be developed over time.

Limitations

Although the sample size (N = 41) appears to be adequate, it could have been a limiting factor. Because the study examined several variables (grasp, size, and shape), a larger sample may provide more generalizable results. Participants of the study were all from the Toledo, Ohio, area, which may also decrease generalizability of the results. Although the age range was from 18 to 55, the majority of participants were University of Toledo students for convenience. Another
limitation of the current study was the nonnaturalistic lab environment in which the study took place.

**Future Research**

Future studies could be completed on a wider age range, on people with disabilities, and on the use of other assistive devices. Future studies could investigate the role of vision in prehensile patterns. Grasping parameters could be compared in participants with eyes closed and eyes open to explore the role of sensation and vision in reaching–grasping parameters. Ultimately, studies should determine whether patients who receive reacher training are more likely to develop the motor learning and control necessary to successfully negotiate reacher use in desired ADLs and are then less likely to abandon it than are patients who do not receive training (or receive limited training) and are expected to develop the motor control for reacher use independently. In addition, reacher designs could be assessed to determine whether a particular design facilitates greater reacher–object interface stability and function within different types of ADLs. ▲

**Acknowledgments**

We thank the College of Health Sciences, University of Toledo, Ohio, for a research award to Katherine Philips for supporting the research study and the Department of Occupational Therapy for use of the facility and equipment for the study. We also thank the participants who made the data collection possible.

**References**


