Grip Strengths and Required Forces in Accessing Everyday Containers in a Normal Population

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Key Words: dynamometer and pinch meters • hand functions • hand strength testing

Objective. A commonly adhered to operating principle in occupational therapy clinics is that a person must exhibit 20 lb of grip strength before his or her hand is considered "functional." This study examined the relationship between hand and finger grip performances with the forces required to open common household containers.

Method. The grip and pinch strengths of 49 college students were obtained using dynamometry. The forces required to open six common household containers were measured using Force Sensing Resistors® attached to each container.

Results. Weak correlations were found (r = -.179 to r = .333) between grip and pinch strength performances and the forces used to operate the accessing mechanisms of the containers. Analyses of variances demonstrated significantly greater grip and pinch strength performances in men than in women (ps < .05) but no significant difference between the genders in the forces generated to open the containers (ps > .05).

Conclusions. In a normal population of college students, the premise that greater hand strength affords greater performance in accessing everyday household containers was not supported. Implications suggest that grip and pinch dynamometry are not conclusive evaluative tools for predicting hand function while opening a select group of containers. The relationship between traditional dynamometry and hand performance during a variety of functional tasks needs to be examined in clinical populations as well.

Functional use of the hand is essential for the human to perform the wide variety of occupations necessary for everyday life. People use their hands to feed and groom themselves, explore their environments, earn a living, communicate, and pursue their leisure occupations. Currently, the hand is commonly evaluated by using grip strength and elapsed time during specific tasks as a measure of hand function. These parameters do not adequately define "function" of the hand.

Occupational therapists in many physical disability settings use gross hand grasp and pinch strengths as baseline evaluation measures (Mathiowetz, Weber, Volland, & Kashman, 1984). Throughout the rehabilitation process, and again as a regular portion of reevaluations, these measurements often epitomize the "measurable" part of the treatment goals (Desrosiers, Bravo, Hebert, & Mercier, 1995; Peterson, Petrick, Connor, & Conklin, 1989). The assumption underlying these goals is that increased strength equals increased function. Philips (1990) and Nalebuff and Philips (1990) stated that grip strength of at least 20 lb, as measured by the Jamar™ dynamometer¹, and 5 lb to 7 lb of pinch strength, as measured by a standard pinch meter, are neces-

¹Available from Jamar™, PO Box 89, Jackson, Michigan 49204-0089.

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sary to perform most activities of daily living (ADL).

Agnew and Maas (1982) stated that an evaluation of a person's performance in ADL provides more useful information about the person's abilities than does grip strength. Such a statement is given credence when one observes clients with severely deformed hands and poor grip strength who remain capable of performing a surprising range of hand functions.

In addition to hand and pinch dynamometry, there are other assessment tools that use time as the critical measure for hand function. McPhee (1987) described 10 tests of hand function that focus on the movement time required to complete the task: Quantitative Test of Upper Extremity Function (Carroll, 1965), Hand Function Test (Jebsen, Taylor, Trieschman, Trotter, & Howard, 1969), Hand Function Test for the Rheumatoid Hand (MacBain, 1970), Functional Assessment of the Rheumatoid Hand (Clawson, Souter, Carrhum, & Hymen, 1971), Simulated Activities of Daily Living Examination (Potts, 1972), Smith Hand Function Evaluation (Smith, 1973), Physical Capacity Evaluation (Bell, Jurek, & Wilson, 1976), Functional Test (Wilson, 1984), Box and Block Test (Mathiowetz, Volland, Kashman, & Weber, 1985), and Nine Hole Peg Test (Mathiowetz, Weber, Kashman, & Volland, 1985). However, movement time is not an accurate description of hand function because measuring movement time without regard to quality of movement is not a complete indication of hand function (McPhee, 1987).

Although there are studies that looked at functional tasks (Egger et al., 1995; Sollerman & Ejeskar, 1995), few measured the grip forces needed to perform these tasks. Forcino (1995) examined prescription medicine containers and the ease with which persons with arthritis could open them. Klopsteg and Wilson (1968) examined the grip forces needed to remove the cap from a tube of toothpaste as a step toward the development of an upper-extremity prosthesis.

Populations with compromised upper-extremity strength or systemic disease, such as arthritis, may be at a greater risk for damaging joints secondary to decreased joint, muscle, or bone integrity. This is particularly true when they perform activities requiring increased force (Walker, Davidson, & Erkman, 1978). Metacarpophalangeal joints with active synovitis are easily damaged by unsuitable loading (Brattstrom, 1975). Patrick, Aldridge, Hamilton, and Doherty (1989) found that persons with nodal generalized osteoarthritis and persons with erosive osteoarthritis demonstrated reduced grip strength compared with persons with clinically normal hands. A person with rheumatoid arthritis has about one tenth the grip strength of a person in the normal population. Pinch strength is approximately one quarter and time manipulation of objects is nearly twice that of the normal population (Walker et al., 1978). Lamoreaux and Hoffer (1995) found that persons with congenital or acquired radial deviation deformities experience decreased grip strength. Additionally, persons with carpal tunnel syndrome often experience a decrease in grip and pinch strengths (Amis, 1987; Radwin, Oh, Jensen, & Webster, 1992), particularly postoperatively (Gellman, Kan, Gee, Kuschner, & Botte, 1989; Leach, Esler, & Scott, 1993). In some cases, their grip and pinch strengths do not return to preoperative status (Young et al., 1989).

The objective of this study was to determine the amount of grip force necessary to access the contents of common household containers. We proposed that no relationship would be found among grip, lateral pinch, tip-to-tip pinch, and three-jaw chuck pinch dynamometry performance and the force generated in accessing the containers. Knowledge of grip forces needed to access these containers will aid therapists in guiding clients in areas of energy conservation and joint protection.

Method

Participants

The sample consisted of 49 students from the University of North Carolina at Chapel Hill, including 9 men 24 to 37 years of age and 40 women 20 to 52 years of age. All participants self-reported to be in good health with no neuromuscular or orthopedic conditions that would adversely affect their ability to open containers.

Instruments

A standard hand Jamar dynamometer was used to measure grip strength, and a B & L Engineering pinch meter was used to measure pinch strength (i.e., lateral, tip-to-tip, three-jaw chuck). Both the dynamometer and the pinch meter were calibrated before initiation of the study.

Hand pressures exerted on six common household containers with different types of lids or operating mechanisms were recorded using Force Sensing Resistors® (FSRs)\(^3\). A nonlinear regression curve fit method with graded known weights was used to calibrate the sensors (Motulsky, 1995). The sensors were placed on the areas of the containers identified in a pilot study as prime for finger and hand contact. The six containers included a dual-pinch safety squeeze bottle, small and large prescription medicine bottles that required push down and rotation movements, an over-the-counter medicine bottle that required alignment and pop-off motion for the lid, an aerosol can of air freshener, and a trigger pump spray bottle (see Figure 1). A PC Innovation Road Warrior 75 MHz laptop Pentium computer with a Keithly Metanalytic DAS card-1001 ar-

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2Available from B & L Engineering, 3002 Dow Avenue, Suite 416, Tustin, California 92780.

3Available from Interlink Electronics, 545 Flynn Road, Camarillo, California 93012.

4Available from PC Innovation, 4011 Capital Boulevard, Raleigh, North Carolina 27604.
A digital-to-analog board was used to record the data at a sampling rate of 50 Hz for 500 samples.

Procedure

Before data collection, informed consent was obtained. Data were collected over a 10-day period, with each participant participating in one 30-min session. A random number-generating algorithm was used to assign participants to one of four groups in a counterbalanced design. Participants performed either the grip and pinch measurements or the force on the container measurements first, depending on their group assignment. Each participant experienced the following conditions: the hand-grip dynamometer, lateral pinch meter, tip-to-tip pinch meter, three-jaw chuck pinch meter, the small prescription medicine bottle, the large prescription medicine bottle, bottle with pop-off lid, bottle with pop-off lid, trigger pump spray bottle, and the aerosol spray can.

American Society of Hand Therapists standardized positioning was used in obtaining all dynamometry measurements (Mathiowetz et al., 1984). To measure grip, participants were directed to perform 3 maximum voluntary contractions (MVCs) by squeezing the dynamometer with the handle set on the second position. To measure pinch, participants were asked to perform 3 MVCs by squeezing the pinch meter in three different finger positions: the lateral, the tip-to-tip, and the three-jaw chuck. A 30-sec rest period between trials was provided. Participants were instructed in how to avoid using the Valsalva maneuver while performing these grip and pinch measurements before data collection. Hand grip and pinch strength measurements were obtained for both limbs.

During the container-opening procedure, participants stood in a designated 1-ft² area in front of a 32-in.-high table on which the containers were arranged and identified with a number. The participant was given the following verbal instructions: "I want you to pick up container number X and open the container or operate the mechanism allowing you to open or access the contents three times in a row." Three times was chosen in order to obtain the best indication of performance. The instructions were modified to match the type of container being accessed.

Data Analysis

A Pearson product-moment correlation was performed between dynamometer performances and the container sensors. An analysis of variance was performed on gender for the seven sensors and for the grip and pinch strengths on the six levels of order for each sensor, on each sensor, and on hand dominance for each grip and pinch strength measurement.

Results

The correlation coefficients between the dynamometer performances and the container sensors ranged from -.179 to .333 (see Table 1). Figure 2 illustrates the means and standard deviations by gender for each dynamometric condition, and Figure 3 illustrates the means and standard deviations of force applied by gender for each sensor. The mean force values recorded by all sensors ranged from 2.23 lb (SD = 2.21) on sensor 2 (attached to the small prescription medicine bottle) to 12.67 lb (SD = 6.34) on the bottle with the pop-off lid. During some trials, no data were collected because the participant did not apply any force to the sensor when opening the container. This occurred for all of the containers except the bottle with the pop-off lid, which, because of its design, required participants to apply force on a specific area on the container's lid. As a result, data are missing from the small prescription medicine bottle's sensor 1 (7 trials) and sensor 2 (15 trials), the aerosol spray can sensor (2 trials), the trigger pump spray bottle sensor (1 trial), and the large prescription medicine bottle sensor (4 trials).

A significant difference was found between genders on all the grip and pinch strengths (ps < .05; see Figure 2), whereas no significant gender effects were demonstrated on any of the sensors (ps > .05; see Figure 3). No significant hand-dominance differences were demonstrated for the grip and pinch strengths (ps > .05) or for the seven sensors (ps > .05). No significant order effects were demonstrated (ps > .05).

Discussion

Our results indicate that only weak relationships exist among grip, lateral pinch, tip-to-tip pinch, and three-jaw chuck pinch dynamometry performances and the forces generated in accessing six common household containers. Despite the significantly greater grip strength in the men, their performance on accessing the containers was not sig-
Table 1
Pearson Product–Moment Correlations Between Grip–Pinch Strengths and Container Sensors

<table>
<thead>
<tr>
<th>Container</th>
<th>Grip Right</th>
<th>Grip Left</th>
<th>Lateral Right</th>
<th>Lateral Left</th>
<th>Three-Jaw Chuck Right</th>
<th>Three-Jaw Chuck Left</th>
<th>Tip-to-Tip Right</th>
<th>Tip-to-Tip Left</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dual-pinching squeeze bottle</td>
<td>.012</td>
<td>.014</td>
<td>.009</td>
<td>-.062</td>
<td>-.062</td>
<td>.023</td>
<td>-.098</td>
<td>.023</td>
</tr>
<tr>
<td>Small prescription medicine bottle 1</td>
<td>.203</td>
<td>.185</td>
<td>.315</td>
<td>.298</td>
<td>.048</td>
<td>.210</td>
<td>.022</td>
<td>.096</td>
</tr>
<tr>
<td>Small prescription medicine bottle 2</td>
<td>.105</td>
<td>.054</td>
<td>.296</td>
<td>.276</td>
<td>.279</td>
<td>.263</td>
<td>.279</td>
<td>.316</td>
</tr>
<tr>
<td>Bottle with pop-off lid</td>
<td>.126</td>
<td>.138</td>
<td>.110</td>
<td>.064</td>
<td>.099</td>
<td>.054</td>
<td>.333</td>
<td>.299</td>
</tr>
<tr>
<td>Aerosol spray can</td>
<td>-.037</td>
<td>.019</td>
<td>-.010</td>
<td>-.035</td>
<td>.175</td>
<td>.070</td>
<td>.068</td>
<td>.071</td>
</tr>
<tr>
<td>Trigger pump spray bottle</td>
<td>.048</td>
<td>.155</td>
<td>.085</td>
<td>.212</td>
<td>-.047</td>
<td>.008</td>
<td>-.012</td>
<td>.007</td>
</tr>
<tr>
<td>Large prescription medicine bottle</td>
<td>-.132</td>
<td>-.179</td>
<td>-.043</td>
<td>-.098</td>
<td>.160</td>
<td>-.019</td>
<td>.252</td>
<td>-.008</td>
</tr>
</tbody>
</table>

Note: Small medicine bottle contained two sensors.

significantly different than that of the women (see Figures 2 and 3). This disparity in dynamometry performance suggests that in a normal population, greater grip strength does not necessarily improve a person’s ability to open the types of containers selected for this study.

Although the lowest grip strength performance in this sample was 40 lb and the lowest pinch strength performance was 6 lb, the range of recorded sensor data suggests that one can generate sufficient force to open these containers with less than 20 lb of grip strength. For example, the lowest value recorded for the trigger pump spray bottle was 2.31 lb, which was sufficient to access the container’s contents. Thus, the low mean force values recorded in opening the containers required much less than the 20 lb of grip and 6 lb to 7 lb of pinch reported by Philips (1990) and Nalebuff and Philips (1990) to have functional use of the hand.

Although the mean forces for all the sensors were less than 20 lb, the maximum force recorded by the sensors ranged from 25.38 lb on the bottle with the pop-off lid to 48.59 lb on the aerosol spray can. These higher force values could be due to inefficient grip configurations that prevented opening the containers with less force. An example noted was when some participants used their index finger on the pop-off lid in order to create a counterforce, thus preventing the lid from dropping to the floor after its release. Each participant tended to perform with little variation while accessing a given container. That is, if a participant used an inefficient technique the first time in accessing a particular container, he or she tended to use the same inefficient technique on subsequent movements for that container.

Although hand and finger dynamometers have and continue to provide useful MVC data, performance in contextually relevant situations will reveal a truer picture of a client’s functional abilities. Attention focused on the occupational demands unique to each client is essential to providing treatment recommendations that are attuned to the client’s needs. Therefore, a knowledge of the forces required to access a variety of containers will equip therapists with appropriate treatment recommendations.

This study had several limitations. The sensors, although rated well for measuring static forces perpendicular to the sensor, were not designed for measuring the dynamic pressures generated by the human hand. In addition, placement of the sensors on some of the containers was not opti-
Figure 3. Means and standard deviations of force applied to each container by gender. Note. \( n = 49 \) for the dual-pinch safety squeeze bottle (Dual) and bottle with pop-off lid (Pop Off); \( n = 48 \) for the trigger pump spray bottle (Trigger Spray); \( n = 47 \) for the aerosol spray can (Aerosol); \( n = 45 \) for the large prescription medicine bottle (Large Med); \( n = 42 \) for the small prescription medicine bottle sensor 1 (Small Med 1); \( n = 34 \) for the small prescription medicine bottle sensor 2 (Small Med 2).

Conclusion

Using a normal population, this study found weak correlations between hand and finger strength and the forces generated to operate the accessing mechanisms of six common household containers. Although functional use of the hand includes more than opening containers, this study demonstrated that hand grip and pinch dynamometry did not have a strong relationship with opening these containers. Inclusion of functional occupations (e.g., opening containers relevant to the client) in evaluation and treatment would be beneficial by yielding truer task demands and performances unique to each client. ▲

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References


