DESIGN RESOURCES

DR-19 Power Grip Forces for Wheeled Mobility Users

Center for Inclusive Design and Environmental Access

DR #19: Power Grip Forces for Wheeled Mobility Users

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Question: What are the most appropriate power grip forces on which to base design decisions?

Issue and Importance to Universal Design

The design of hand-operated products and environmental features require an understanding of the grip strength capacity of potential users, including individuals with disabilities. A commonly used grip posture is the power grip, wherein the handle is perpendicular to the forearm, and the handle is squeezed by the partially flexed fingers and the palm while the thumb applies counter pressure. Measurements of power grip strength also serve as a clinical tool for assessing the upper extremity function of individuals by comparing with normative data.

Existing Research/Evidences

The majority of functional hand anthropometry studies have focused on able-bodied individuals stratified by gender and age (e.g., Bohannon et al., 2006; Crosby et al., 1994; Mathiowetz et al., 1985) with some emphasis on elderly populations (e.g., Bear-Lehman et al., 2003; Brennan et al., 2004; Desrosiers et al., 1995). Hand grip strength data for users of wheeled mobility devices that can be applied to design is scarce. Further, data on grip strength for persons with disabilities has been recorded primarily for clinical purposes and for specific impairments or disabilities with very limited sample sizes, e.g., arthritis (Chen and Giustino, 2007), rheumatoid arthritis (Fraser et al., 1999), multiple sclerosis (Chen et al., 2007), stroke (Heller et al., 1987). Very few studies provide this data in a design context (e.g., Imrhan and Loo, 1989b, 1989a; Peebles and Norris, 1998; Steinfeld, 1986; Voorbij and Steenbekkers, 2002). See D'Souza et al. (2011) for a more in-depth literature review.

As part of the Anthropometry of Wheeled Mobility (AWM) project, the IDeA Center has been developing a comprehensive anthropometry database of manual chair, powered chair and scooter users in the U.S. (Steinfeld et al., 2010). Measurements of maximum isometric power grip strength measured on the dominant arm from 495 wheeled mobility device users in this study have been used as the basis for recommending permissible force values as guidelines for inclusive design. Recommendations for handle diameters and lengths based on hand grip sizes and hand breadth measurements have also been provided.

Quality of Existing Evidence

Lack of design data on the power grip strength capabilities of persons with disabilities limits the ability of designers and manufacturers to design hand-operated products that can be easily operated by wheeled mobility users.

Existing Design Guidelines

Current design guidelines by the U.S. Access Board recommend a maximum permissible force of no greater than 5lbf (22.2 N) for the activation of controls (U. S. Access Board, 2004). These guidelines also advise against the use of operable parts that require two-hands, tight grasping, pinching, or twisting of the wrist, in order to accommodate users that may have limited upper extremity strength and dexterity. However, this force limit recommended does not pertain specifically to power grips, but applies to hand grip forces in general.

Summary of the AWM findings

Measurement of power grip strength included the average of three maximum grip strength trials on the dominant hand using a Jamar hydraulic hand dynamometer in two different postures:

- Power grip with the arm in full extension: for which the gripping arm was held out in front parallel to the floor with the elbow fully extended and the shoulder fully adducted and neutrally rotated, and
- Power grip with the elbow flexed 90 degrees, with the shoulder adducted and neutrally rotated.

In both postures, the forearm and wrist were in a closely neutral and comfortable position. The hand dynamometer was set to Level 2 providing a grip span width of 3.6 cm. While a few participants were unwilling or unable to exert any voluntary grip force (e.g., persons who have a spinal cord lesion higher than C7/T1), the inability to replicate a grip configuration (e.g., due to pain or discomfort) or produce voluntary force exertions without assistance also resulted in the exclusion of the individual from that particular grip strength measurement. The mean value of three trials was taken to represent the maximum voluntary exertion. Of the 495 individuals that were administered the test, only 93% of manual chair users, 79% of powered chair users, and all but one of the 30 (97%) scooter users could complete three repetitions of the power grip for each of the two arm postures. Detailed descriptions of the measurement methods, composition of the study sample and findings can be found in D'Souza et al. (2011) and Joseph et al. (2010).

Figure 1 provides the mean and 5^{th} percentile values for power grip strength across the different groups of wheeled mobility users, and represents grip strength data for just these individuals that demonstrated some grasping ability. The 5^{th} percentile power grip strength values with the arm fully extended provides a conservative threshold value for determining the maximum permissible force when using hand-operated parts in a power grip where typically the arm is outstretched forwards e.g., grasping a door handle. Data presented in figure 1 suggests that at least 95 percent if not more of the wheeled mobility users in the AWM study could exert a voluntary power grip force that equals or exceeds 5 lbf. Also, on average, power grip strength in the flexed elbow posture was 3-5% less than corresponding measurements with the elbow in full extension (D'Souza et al., 2011).

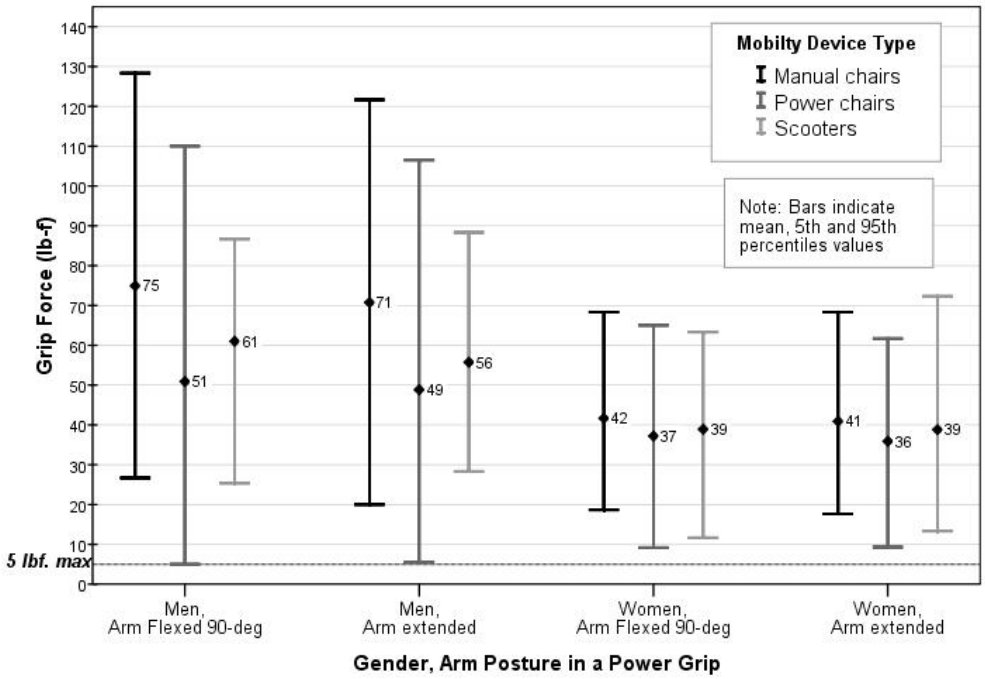

Figure 1: The mean, 5th and 95th percentile values for power grip (lbf) in two arm postures (elbow flexed vs. arm extended) across gender and device type.

Based on Figure 1 and other findings on hand anthropometry from the AWM study, the following guidelines for designing products involving a power grip are recommended (D'Souza et al., 2011; Steinfeld et al., 2010):

1) Use of operable parts preferably should not require power grip force in excess of 5 lbf. (17.5 N) as prescribed in the current ADA-ABA accessibility guidelines, in order to accommodate most wheeled mobility device users who have at least some grasping capability based on the AWM study sample.
2) Tasks and products that require operation of controls or object grasping should allow for both right- and left-handed operation, given that more than 25% of wheeled mobility device users in this study were left-hand dominant. Adequate clear floor space should be provided to access controls and switches from either the left or the right (see Design Resource #16 on 'Clear floor space when reaching & grasping').
3) Designing home or occupational products and activities which require the use of both hands should be limited or avoided in order to accommodate the large proportion of wheeled mobility device users who possess functional capabilities in only one hand.
4) Hand-operated products and environmental features for use by the general public should be designed acknowledging that grip strength is significantly affected by gender and disability, with:
   a. a large portion of wheeled mobility device users having limited or no grasping ability,
   b. power grip and pinch grip strength among wheeled mobility device users in the AWM study being approximately 50% of normative values for grip strength of adults,
   c. power grip strength among women wheeled mobility users being about 40% lower than men, and
   d. powered chair users displaying the weakest power grip strength among users of the different wheeled mobility devices

5) Based on measurements of hand breadth, it is recommended that the minimum length for handles to be held using a power grip should be no less than 105 mm to provide adequate contact between surfaces of the palm and handle.
6) Based on measurements of grip sizes, it is recommended that the diameter of circular gripping surfaces in a power grip such as handles, handrails and grab bars should range between 33 mm - 50 mm (1.3 in. - 1.7 in.). However, the 32 mm - 38 mm (1.25 in. - 1.5 in.) size range prescribed in current standards for accessible design should be followed when compliance with U.S. design standards is desired.

Examples of Application

Grip strength data from the AWM study can help designers employ suitable force exertion criteria when designing hand-operated products or features (e.g., handles, knobs, levers, work tools) as well as identify tasks that require power grip force exertion that exceed the capabilities of most users and need to be redesigned possibly through use of technological interventions and assistive devices. For example, many existing faucets, spigots, doorknobs, and locks require tight grasping and/or pinching to operate, as well as many consumer products such as a bottle of water or medication. Lever-shaped handles and faucets eliminate tight grasping and pinching while technological interventions such as automatic faucets and doors eliminate the need for grasping and pinching entirely.

Research Needs

The data provided here is only a starting point for accessible design. When using features in the environment, several other interrelated design parameters such as the orientation, size and shape of the object, direction of force exerted, and operating height, etc. can together affect ones' ability to grasp and apply force, and to varying degrees depending on the type and severity of a person's disability. Additional research is required to quantify the extent of these interactions towards developing more comprehensive and inclusive design criteria.

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Relevant Design Resources

DR #16: Clear floor space when reaching & grasping

DR #18: Pinch grip forces for wheeled mobility users

DESIGN RESOURCES

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