DESIGN RESOURCES

DR-18 Pinch Grip Forces for Wheeled Mobility Users

Center for Inclusive Design and Environmental Access

DR #18: Pinch Grip Forces for Wheeled Mobility Users

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Last Updated: January 4, 2011

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

Issue and Importance to Universal Design

In the process of operating controls or performing activities of daily living, a variety of pinch grips get used e.g., a lateral (key) pinch, pulp pinch, thumb-forefinger tip pinch, palmar pinch. The universal design of hand-operated products and environmental features should apply an understanding of the gripping abilities of the broadest range of potential users, including individuals with disabilities.

Existing Research/Evidences

The majority of anthropometry studies on pinch strengths have focused on samples of able-bodied individuals stratified by gender and age (e.g., Boatright et al., 1996; Crosby et al., 1994; Desrosiers et al., 1995; Mathiowetz et al., 1985). Available data on pinch grip strength obtained from persons with disabilities has been recorded predominantly for clinical purposes and for specific impairments or disabilities with very limited sample sizes, e.g., arthritis (Chen and Giustino, 2007), multiple sclerosis (Chen et al., 2007). Further, very few studies provide pinch grip strength data in the context of product design (e.g., Imrhan and Loo, 1989; Peebles and Norris, 1998; Steinfeld, 1986). See D'Souza et al. (2010) for a more in-depth literature review.

The Anthropometry of Wheeled Mobility (AWM) project at the IDeA Center has been developing a comprehensive anthropometry database of manual wheelchair, powered wheelchair and scooter users in the U.S. (Steinfeld et al., 2010). Measurements of maximum isometric pinch grip strength measured on the dominant arm from 495 wheeled mobility device users in this study have been used as the basis for developing guidelines for the inclusive design of products.

Quality of Existing Evidence

Lack of design data on the pinch grip capabilities of persons with disabilities including wheeled mobility users limits the ability of designers and manufacturers to design more inclusive hand-operated products.

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, the 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 pinch grip strengths included the average of three grip strength trials on the dominant hand using a Jamar pinch gauge in two different postures (D'Souza et al., 2011). These included a lateral pinch grip measured between the thumb pulp and the radial aspect of the second digit, and a thumb-forefinger pinch grip measured between the tips of the thumb and forefinger (Fig. 1).

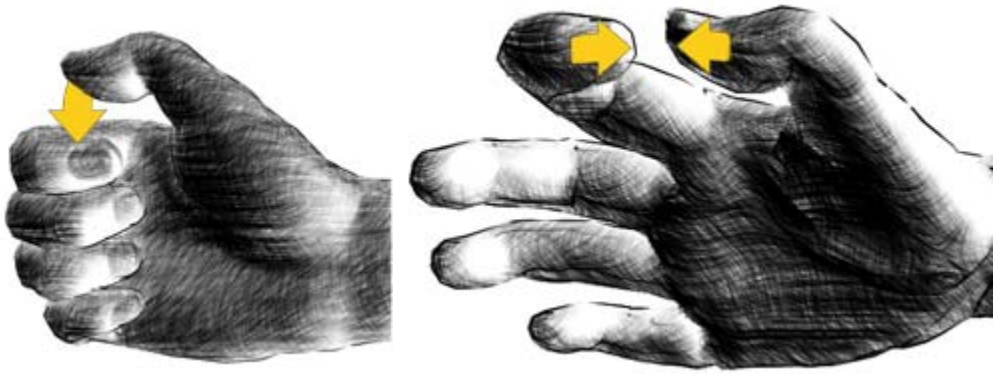

Figure 1: Lateral pinch (left) and thumb-forefinger tip pinch (right) grips

For both grips, the shoulder was adducted and neutrally rotated, and the forearm and wrist were in a closely neutral and comfortable position. 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, recordable pinch grip strength values were obtainable from 88% of manual chair users, 74% of powered chair users, and 97% of the scooter users. For thumb-forefinger grips, these proportions were 86%, 68%, and 97%, respectively. 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 2 provides the mean, 5^{th} and 95^{th} percentile values for pinch grip strength across users of the different wheeled mobility types that demonstrated some grasping ability. The 5^{th} percentile pinch grip strength values provide a conservative threshold value for determining the maximum permissible force when using hand-operated parts that requires a pinch grip e.g., turning a key. Data presented in figure 2 suggests:

- On average, pinch grip strength values using a thumb-forefinger tip grip were lesser than a lateral pinch grip
- Very few wheeled mobility users can exert pinch forces greater than 5lbf.

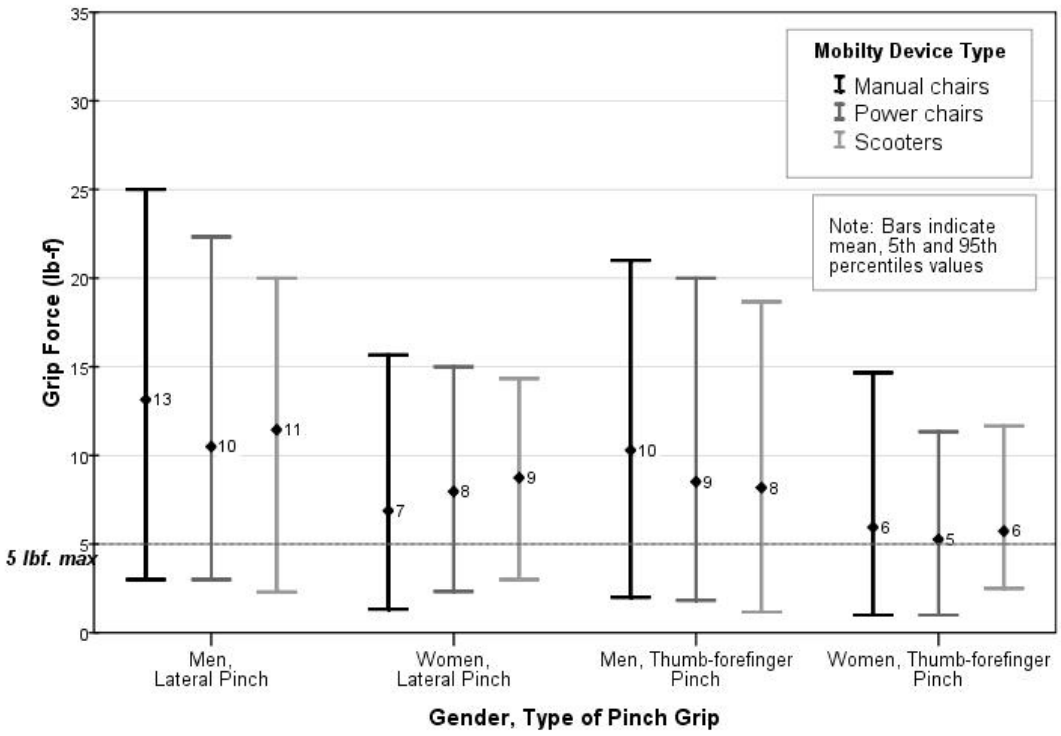

Figure 2: The mean, 5th and 95th percentile values for lateral pinch (lbf) and thumb-forefinger tip pinch grip (lbf) across gender and device type.

Based on the presented data and related findings from the AWM study, the following design guidelines related to pinch grips are recommended (D'Souza et al., 2011; Steinfeld, 1986; Steinfeld et al., 2010):

1) Designers should reduce the need for high precision grip postures and/or pinch forces given the lack of finger dexterity, motor control or pinching capabilities of persons with disabilities. This can be achieved by designs that allow operation using alternate grip configurations such as a flat hand, fist or a more convenient power grip or hook grip. Broader handles and larger gripping surface areas facilitate stronger grips.
2) When a precision pinch grip is required, a lateral pinch is recommended over a thumb-forefinger tip pinch grip as:
    a. A lateral pinch grip provides a larger finger contact surface resulting in individuals with limited finger dexterity and strength to be more likely to form this grip.
    b. The maximum pinch forces in a thumb-forefinger tip grip are significantly less compared to a lateral pinch grip.
3) Use of operable parts preferably should not require exertion of lateral pinch grip forces in excess of 2 lbf. (9 N) so as to accommodate most wheeled mobility device users who have at least some grasping capability.
4) Tasks and products that require operation of controls or object grasping should allow for both right- and left-handed operation, given that
    a. 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 DR #16: Clear floor space when reaching & grasping)
    b. A large proportion of wheeled mobility device users possess functional capabilities in only one hand

5) 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. Pinch grip strength among women wheeled mobility users being about 40% lower than men.

Examples of Application

Grip strength data from the AWM study can help designers employ more inclusive design criteria when developing new designs, as well as identify tasks that require pinch 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 drawers or cabinets require tight pinching to open but adding a more ergonomically designed handle and rollers to the bottom of the drawer allows it to open with ease.

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 a person's ability to grasp and apply force, and is further affected by the type and severity of their disability (Steinfeld, 1986). Additional research is required to quantify the extent of these interactions as well as in dynamic vs. isometric gripping conditions towards developing more comprehensive and inclusive design criteria. Currently work on integrating the research from the AWM study and prior research by Steinfeld (1986) is underway.

Acknowledgement
This research was supported by the U.S. Access Board (contract # TDP-02-C-0033) and the National Institute on Disability and Rehabilitation Research (NIDRR) through funding of the RERC on Universal Design (Grant # H133E990005). The opinions expressed herein are those of the authors and do not represent the policy of the Access Board, nor of NIDRR.

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Relevant IDEA Center Publications

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Relevant Design Resources

DR #16: Clear floor space when reaching & grasping

DR #19: Power grip forces for wheeled mobility users

DESIGN RESOURCES

DR- 18 Pinch Grip Forces for Wheeled Mobility Users

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