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MANIPULATORS AND UPPER-EXTREMITY PROSTHETICS

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In 1946–47, early in the government-sponsored Artificial Limb Program coordinated by the National Academy of Sciences, UCLA conducted extensive experiments on motions and gripping forces required for selected and common activities of everyday living. (These were deliberately selected as representative of independent living even for severely disabled bilateral amputees, though many of them were also difficult for unilateral amputees. Some were mutually exclusive, like holding a knife and holding a fork during cutting of meats, so that even a unilateral must perform either one or the other with a prosthesis. Industrial activities were not specifically studied, on the presumption that vocational guidance could locate suitable jobs among the tremendous variety requiring motions and forces no more severe than those required in everyday living and thus within the capacity of rehabilitated amputees.)

The typical gripping or pinching forces for a great many tasks were found to be 3 pounds or less at the finger tips, with only occasional tasks requiring as much as 6 pounds. The maximum pinching force encountered (pulling on shoes under certain conditions) was 14 pounds. Such high forces could be avoided fairly easily by use of a loop on the shoes, by further unlacing, or by wearing elasticized shoes. Independently, it was found that most amputees wearing voluntary-opening hooks closed by rubber bands typically wore only enough rubber bands to generate about 3 pounds pinching force at the hook tips with objects about ½ inch in thickness. Very few amputees, mostly bilateral, used as much as 6 pounds pinching force on at least one hook. Much higher forces without prehension could be exerted in lifting, pushing, pressing, etc., with the outer surfaces of the hook "fingers."

Accordingly, standards were set for terminal devices to pinch 3 to 3½ pounds readily but preferably to permit occasional development of 6 to 8 pounds. The Northrop-Sierra voluntary-opening hook closed by two coiled clock springs permits this choice by constant engagement of one spring but selective additional engagement of the second spring by moving a button on the operating lever. To engage or release the second spring, this button may be moved by bumping it against a fixed object in the environment or by using the opposite arm.

PREHENSION PATTERNS

The UCLA studies also explored the various finger motions used in a wide variety of activities of daily living. Probably the most frequently used form of prehension was the so-called "lateral," with the thumb engaging against the distal and intermediate segments and the intermediate knuckle of the index finger. This type of grip, very common in everyday activities, provides quite a stable grasp of objects with relatively flat sides. It is not, however, suitable for large objects, which tend to be expelled from the V-shaped notch between the thumb and index finger.

Larger objects are typically grasped by swinging the thumb away from the position of lateral prehension around toward the little finger so as to engage the tips of the index and middle fingers. Typically the index and middle fingers move inward on nonparallel planes so as to approach the thumb in a three-jaw chuck fashion.

Initially it was assumed that heavily curved fingers and thumb, all moving simultaneously, would be most versatile. Thereby large objects could be surrounded by the curved fingers and the flexed thumb in a fist-like grip, while small objects would be picked up by fingernails or mechanical equivalents. The concept of fist grip plus fingertip grip was later found to be a fallacy because the average objects of everyday living, such as knife, fork, pencil, etc., were engaged only in a[n] unsteady grip on the small fingertips.

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