International Journal of Industrial Ergonomics 44 (2014) 761–768

Contents lists available at ScienceDirect

International Journal of Industrial Ergonomics

journal homepage: www.elsevier.com/locate/ergon

Common patterns of voluntary grasp types according to object shape, size, and direction

Kyung-Sun Lee [a, b], Myung-Chul Jung [a, *]

[a] Department of Industrial Engineering, Ajou University, Suwon 443-749, Republic of Korea
[b] Instrumentation & Control/Human Factors Research Division, Korea Atomic Energy Research Institute (KAERI), Daejeon 305-353, Republic of Korea

ARTICLE INFO

Article history:
Received 29 August 2013
Received in revised form
10 June 2014
Accepted 26 August 2014
Available online 19 September 2014

Keywords:
Pattern of grasp types
Object property
Grasping
Pinching
Human behavior

ABSTRACT

This study aimed to investigate commonly used voluntary grasp types according to object shape, size, and direction, with the participation of 50 students. The grasp type classifications consisted of grasping (G) and pinching (P) and were further subdivided based on the number and use of fingers (T, thumb; I, index finger; M, middle finger; R, ring finger; or L, little finger) and palm (P). Seven grasp types were commonly used by the participants: 5P (TIMRL), 5G (TIMRL), 3P (TIM), 4P (TIMR), 2P (TI), 4G (TIMR), and 3G (TIM). Participants most frequently held cylindrical and square pillar objects using 5G (TIMRL) and 5P (TIMRL), respectively. 3P (TIM) was commonly used to hold 1- to 4-cm objects, whereas 5G (TIMRL) and 5P (TIMRL) were commonly used to hold 8- to 12-cm objects. The up-down direction-oriented objects were commonly held with 5G (TIMRL), and the left-right direction-oriented objects were held with 2P (TI), 3P (TIM), and 5G (TIMRL). These results provide basic information regarding common patterns of human grasp types.

Relevance to industry: This paper provides a guideline on the selection of hand tools in industry in terms of their shapes and sizes, so that workers can use appropriate hand postures to reduce hand stresses.

1. Introduction

The thumb and four fingers of the hand comprise bones, muscles, ligament, tendons, fascia, and vascular structures encapsulated by skin (Mackenzie and Iberall, 1994). The structure, utility, and mechanisms of the hand are more complex than those of other body parts. These characteristics of the hand enable various hand functions and postures. Therefore, the human hand is very useful in activities of daily living (ADL), as well as occupational and industrial activities (Domalain et al., 2008). Hand postures include various hand and digit movements for grasping and manipulating objects (Wong and Whishaw, 2004). The main purpose of hand posture is the maintenance of a stable grasp, ensuring that objects are not dropped.

Many researchers have studied the manner in which humans utilize their hands (Kyota and Saito, 2012). Slocum and Pratt (1946) reported that grasping and pinching are common postures in hand functions. Napier (1956) classified grasp types into power and precision grasps. The power grasp was defined as holding an object with the thumb, fingers, and palm; the precision grasp was defined as holding and manipulating an object with the tips of the thumb and fingers. Previous studies classified grasp types on the basis of the part of the hand used (McBride, 1942; Armstrong et al., 1982) and the shapes of objects (Griffiths, 1943; Cutkosky, 1989). Kamakura et al. (1980) divided grasp types into 14 types under four patterns after examining the grasps of 98 general objects in various occupations, sports, and arts according to finger position and contact area. Hwang et al. (2010) and Wang et al. (2012) classified grasp types for touching, wrapping, and pinching on the basis of palm use and number of fingers.

Various grasp patterns are required to successfully interact with various environments and object properties (Fuller and Trombly, 1996). Grasp patterns can be affected by object properties such as shape (Mackenzie and Iberall, 1994), size (Wong and Whishaw, 2004), and direction (Cuijpers et al., 2004). Mackenzie and Iberall (1994) mentioned that object shape delimits the number of fingers that can potentially contact surfaces during grasping. Wong and Whishaw (2004) found that grasp patterns vary more as object size increases. Object size may also influence the transport component of grasping (Boorsma et al., 1994). Object direction may affect the posture chosen for the grasp.

Some previous studies reported common grasp patterns according to object properties. Kyota and Saito (2012) classified grasp types according to object shape. For cylindrical objects, the hands use the most diverse range of postures, including power, lateral,

* Corresponding author. Tel.: +82 31 219 2981; fax: +82 31 219 1610.
E-mail addresses: lks79s@ajou.ac.kr (K.-S. Lee), mcjung@ajou.ac.kr (M.-C. Jung).

http://dx.doi.org/10.1016/j.ergon.2014.08.005
0169-8141/

tripod, parallel mild flexion, circular mild flexion, tip, parallel extension, and adduction grips. Moreover, square pillar objects are held by using the lateral, parallel mild flexion, circular mild flexion, parallel extension, and adduction grips. Overall, hands use the most diverse range of postures to hold cylindrical objects, followed by circular and square pillar objects (Kyota and Saito, 2012). Gentilucci et al. (1991) investigated grasp patterns for holding a large cylinder (6-cm diameter) and a small sphere (0.5-cm diameter); these objects were held using a power grip (i.e., all fingers wrapped around an object) and a pinch grip (i.e., opposition of the thumb and index fingers), respectively. Castiello et al. (1993) reported the natural grasp patterns used to lift cylinders of varying size. The results indicated that subjects commonly use the pinch and power grips for small (0.7-cm diameter) and large (8-cm diameter) cylinders, respectively. Fuller and Trombly (1996) investigated female grasp patterns for holding cup handles; most subjects used four, two or three, and one fingers with the thumb to hold 8-, 4-, and 2-cm cup handles, respectively.

However, previous studies focused on limited object properties and investigated kinematic characteristics (e.g., movement time, velocity, and acceleration) rather than common grasp patterns. There are recently a few studies that analyzed the frequency of different types of grasp use in daily activities (Kilbreath and Heard, 2005; Zheng et al., 2011; Vergara et al., 2014), but they only presented frequency and duration of use of grip types without considering object properties. Moreover, there are insufficient human behavior studies of the variations in grasp types used by humans with respect to various object properties. It needs more detailed information on which fingers are involved in object–hand coupling. Therefore, in the present study, we aimed to investigate commonly used voluntary grasp types according to the properties of objects (i.e., shape, size, and direction). This study specifically analyzed variations in the use of voluntary grasp types as functions of object shape, size, and direction.

2. Methods

2.1. Grasp types

The grasp types were classified as grasping (G) and pinching (P) (Hwang et al., 2010; Wang et al., 2012). Grasping was defined as postures in which the fingers and palm are wrapped around an object and classified according to the number of fingers involved in object–hand coupling. Pinching was defined as postures in which the fingers squeeze the opposite sides of an object, without contact with the palm, and were classified according to the number of fingers involved in object–hand coupling (Table 1). The fingers are abbreviated as follows: T, thumb; I, index finger; M, middle finger; R, ring finger; and L, little finger.

Table 1
Grasp type classification and definitions.

Classification	Definition	Notation
Grasping	1G: grasping with one finger	T, I, M, R, L
	2G: grasping with two fingers	TI, TM, TR, TL, IM, IR, IL, MR, ML, RL
	3G: grasping with three fingers	TIM, TIR, TIL, TMR, TML, TRL, IMR, IRL, MRL
	4G: grasping with four fingers	TIMR, TIRL, TMRL, IMRL
	5G: grasping with five fingers	TIMRL
Pinching	2P: pinching with two fingers	TI, TM, TR, TL, IM, IR, IL, MR, ML, RL
	3P: pinching with three fingers	TIM, TIR, TIL, TMR, TML, TRL, IMR, IRL, MRL
	4P: pinching with four fingers	TIMR, TIRL, TMRL, IMRL
	5P: pinching with five fingers	TIMRL

Table 2
Hand anthropometric data for the participants by gender.

Gender		Age (year)	Body weight (kg)	Height (cm)	Hand length (cm)	Hand width (cm)
Female	Mean	22.8	55.4	163.0	17.3	7.7
	SD	1.7	7.9	5.3	0.8	0.3
Male	Mean	26.1	73.9	176.6	19.1	8.6
	SD	4.7	12.5	6.3	1.0	0.5
Total	Mean	24.7	66.1	170.9	18.4	8.2
	SD	4.1	14.1	9.0	1.3	0.6

2.2. Participants

A total of 50 graduate and undergraduate students (29 male and 21 female) participated in this study. Participants were recruited through flyers posted on campus and were paid $10 for participation. All participants were right-handed and had no history of illnesses or injuries in their extremities in the previous year. The participants' characteristics are as follows [mean (standard deviation (SD))]: age, 24.7 (4.1) years; height, 170.9 (9.0) cm; weight, 66.1 (14.1) kg; hand length, 18.4 (1.3) cm; and hand width, 8.2 (0.6) cm. Table 2 shows the detailed hand anthropometric data by gender.

2.3. Apparatus

Three video cameras (two Samsung MX25E and one Sony DCR-SR100) were placed in front and on both sides of the participant to record the grasp types (Fig. 1). The lenses were focused on the participant's right hand and the object. An adjustable height table was used during the reach to grasp task. The table height followed the recommended standing work surface height for light assembly work tasks (male: 107.0 cm, female 96.0 cm) (Sanders and McCormick, 1993).

The objects in use were 12 cylinders and square pillars made of acrylic panels, ranging from 1 to 12 cm in size. The object shapes were determined according to the study of Hur et al. (2012). The minimum and maximum sizes of objects were chosen on the basis of previous studies analyzing grasp types (Dohle et al., 2000). The objects were all black. Hand length and width were measured by a digital caliper (Konex, H33997). Hand length was measured as the distance from the wrist crease baseline to the tip of the middle finger after the participant's right hand was extended and palm up; hand width was measured as the distance of the hand between

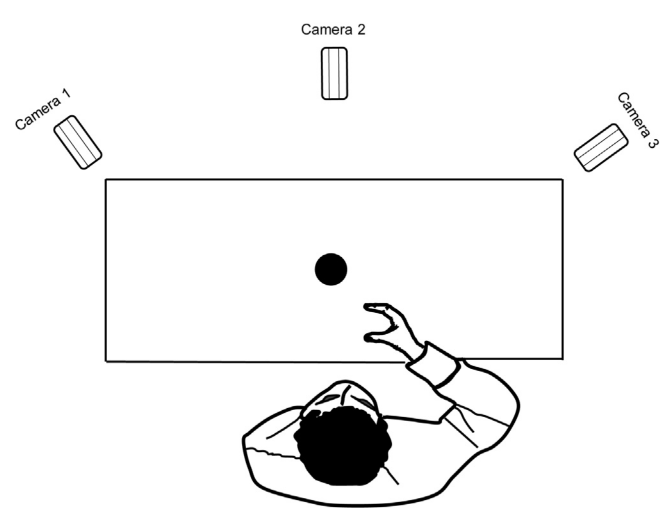

Fig. 1. Experimental setup.