International Journal of Industrial Ergonomics 58 (2017) 38–46

Contents lists available at ScienceDirect

International Journal of Industrial Ergonomics

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

The assessment of a two-handed pinch force: Quantifying different anthropometric pinch grasp patterns for males and females

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ARTICLE INFO

Article history:
Received 16 June 2016
Received in revised form
21 November 2016
Accepted 16 February 2017

Keywords:
Two hands pinch force
Pinch grip width
Chuck pinch
Lateral pinch
Pulp-2 pinch

ABSTRACT

In industrial applications, it is essential to describe and estimate the distinctive nature or features of grip force so as to optimize tool, machine grip, and/or handle designs. Most of the industrial machine's handles require two hands pinch grip force exertion, however, most of the existing research focused on one hand pinch grip force. Each different machine handle's design requires definitely different anthropometric grasp types based on the machine handle shape. This study is therefore aims at examining and investigating the influence of pinch grip pattern, pinch grip width, gender, lean body mass (LBM), body mass index (BMI), and hand dimensions on pinch grip forces by conducting two-hand experiment using a custom-designed measuring tool. Three different types of anthropometric pinch grasp patterns were tested, which are: lateral (key), chuck, and pulp-2. Pinch grips were tested for static maximal voluntary contraction (MVC) forces using a two hands in a snap-type action at two different widths (3.8 cm and 6.8 cm) among forty-six volunteers. The two-handed pinch grip force was also quantified by developing regression models for each anthropometric pinch grasp pattern. The results showed that the pinch grip force was affected by: the pinch grasp pattern, pinch grip width, gender, and hand dimensions. Chuck and lateral pinch forces were not significantly different from each other. Pulp-2 pinch had the lowest pinch forces for males and females. Individuals' medical indexes were calculated to study their significance on the pinch grip force. It was noticed that the LBM index has a significant effect on the pinch grip force compared to the BMI.

Practitioner summary

The study investigates the influence of pinch type, pinch width, gender, body mass, and hand dimensions on pinch grip forces by conducting two-hand experiment using a custom-designed measuring tool. Pinch grip force was affected by pinch type and width. Two hands produce twice the force of a one-handed pinch grip.

1. Introduction

Grip force studies are considered one of the substantial issues that are being under focus in applied ergonomics science. They are absolutely necessary in designing the industrial machines handles or any daily life equipment at work or leisure activities. Ergonomic as a concept is the measurement, analysis, evaluation, and design of system involving human machine task environment interaction for the purpose of enhancing performance, safety and health (Grandjean, 1988; Imrhan, 1996; Mandahawi et al., 2008a). In order to enhance this interaction, knowledge about: human body dimensions, physical strength, limitations, and capabilities are required. Pinch grip force is an important aspect that must be considered when designing tools and equipment, which people use in their technical or social systems. The forceful exertions and repetitiveness are considered essential and major causes of the Cumulative Trauma Disorder (CTDs) in upper extremities (National Institute for Occupational Safety and Health (NIOSH), 1997).

Gripping or squeezing tasks with both hands at different grip widths are used in industry, activities of daily living, or leisure activities. For instance, some industrial tasks require the two handles to be gripped while they are close together with a certain grip width. The grip force may result from the thenar eminence and

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http://dx.doi.org/10.1016/j.ergon.2017.02.006
0169-8141/

thumb opposing the other fingers (Imrhan, 1999). In car manufacturing industry, gripping and snapping seat belt retractors into their housing is another example. Leisure activities include; climbing, horse racing, canoe polo, Brazilian jiu-jitsu, and upper suspension exercises.

In applied industrial operations, pinch gripping tools are used frequently. Hence, it is important to quantify the pinch grip force that is exerted by workers to evaluate effectively the job or the tool design (Ayoub, 1973; McGorry et al., 2010; Dale et al., 2011). Investigating the pinch exertion forces is highly needed in job designing purpose. This could enhance the job performance and lower the CTDs occurrence probability. Many studies pointed that if hand tools have poor ergonomics, then workers' hands and forearms become increasingly subject to a variety of work related musculoskeletal disorders by cumulative trauma such as: tendonitis, strained muscles, carpal tunnel syndrome, nerve impingement, and many others (Kelly et al., 1995; Kattel et al., 1996; Wells and Keir, 1999; Sande et al., 2001; Mirka et al., 2002; Boyles et al., 2003). Therefore, pinch grip force evaluation in the workplace may help in three main aspects, which are: identifying individuals at risk for work related musculoskeletal disorders of the hands and forearms, determining the improvement made over the process of treatment or rehabilitation, and assessing feigned injury (Boissey et al., 1999; Greeves et al., 1999; Abbott et al., 2001; Peolsson et al., 2001; Tredgett and Davis, 2000; Westbrook et al., 2002; Kong et al., 2012).

Generally speaking, the human hand could be in different positions and shapes to grip or touch the materials/objects. It usually depends on how the hand will be used for the desired action. Types of grip include: the crush grip, the pinch grip, and the support grip (Magee, 2014). The pinch grips and support grips (e.g. chuck, lateral, and pulp-2) are widely used in the industrial applications (Aghazadeh, 1994; Shivers et al., 2002). However, the crush grips are commonly used in sport exercises machines (Spindler and Heslep, 2013).

Most of the studies on hand pinch grip force have tested one-handed contraction, usually, the preferred hand at a single fixed pinch grip width. Imrhan and Rahman (1995) tested the pinch width and pinch force for chuck, lateral, and pulp-2 pinch grasp types. However, many industrial tasks and activities are performed using both hands with muscular forces applied simultaneously with both hands (Imrhan and Mandahawi, 2010; Imrhan, 2003; Imrhan, 1999). Therefore, there is a need to measure the two-hand pinch grip force which is one of the objectives of this study.

In Jordanian industry, tools and equipment are used widely for various types of operations. Most of these tools are imported from countries which do not take into account the gripping force for Jordanians populations. Hence, there is a need to evaluate the suitability of these tools for Jordanian operators/workers.

Therefore, the objective of this study is to consider not only one hand pinch grip force, but also to consider studying two hands pinch grip force. The pinch grip force takes into account three types of anthropometric pinches at two different pinch grip widths. This research paper evaluates three different pinch grip forces considering both genders in one experiment. The experiment was conducted on a Jordanian population to enrich the literature about the pinch grip force investigations and to make improvements that may be necessary for comfort, health, and safety in the Jordanian industry. The experimental data and results are uniquely analysed with an insight from the statistical point of view, and regression models have been developed to quantify the two hands maximal voluntary contraction (MVC) pinch force based on different factors. The following hypotheses will be tested:

- The gender, pinch grasp patterns, and pinch width affect the two hands MVC pinch force.
- The hand dimensions (i.e. length, breadth, and thickness) affect the two hands MVC pinch force for each pinch width and each pinch grasp pattern.
- The Body Mass Index (BMI) and Lean Body Mass (LBM) affect the pinch force for males and females

2. Methods

2.1. Subjects

In this study, forty-six healthy college students (i.e. 25 males and 21 females) participated voluntarily. To our knowledge, no subject has any history of musculoskeletal problems. Permission was obtained from the Hashemite University to conduct the force tests and gather the demographic and anthropometric information from the subjects. Letter of consent was signed by all the participants for the purpose of participating this study's experiment.

2.2. Apparatus

A special two-hand measuring force tool has been designed to collect the two hands force data (i.e. pinch grip force). The apparatus is similar to the one that was designed by Imrahn (1999, 2003). It consists of a custom-designed handle attached to a Dillon digital push-pull force gauge (Dillon GL). The Dillon GL is a self-contained measurement device that monitors forces and/or weights (i.e. push/pull) on its built-in load cell. The force capacity is measured in 500 × 0.02 N (50 × 0.02 kg, 110 × 0.05 lb), which is the highest available capacity in the GL Force Gauge Series. Dillon GL Force gauges are affordable digital force measurement devices which include a full set of handy accessories that assist in tension/compression testing applications. Dillon's digital force gauges provide 120% overload protection and a rugged metal die cast enclosure, backlit LCD display, and serial output as shown in Fig. 1.

Fig. 1. Dillon force gauge (Dillon GL).