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Maximum isometric finger pull forces

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ABSTRACT

The current study determined the maximal voluntary isometric forces for a variety of finger pulling tasks. Twenty healthy females, with no history of upper extremity injuries, were asked to use the fingers from their dominant hands and apply their maximal voluntary pull forces for seven conditions that varied in the number of fingers, force application location and interface characteristics. All conditions were tested with and without the use of a glove. However, there was no significant effect of wearing a glove. As expected, the maximum force increased with the number of fingers used and decreased when forces were applied on the finger tip instead of the first distal inter-phalangeal joint. Maximum forces ranged from 59.5 ± 21.4 N when using the index finger tip on a thin ring, to 268.7 ± 77.2 N when using all four fingers on a straight bar.

Relevance to industry: Many industrial tasks require pulling with the finger(s). The current study provides a set of maximal finger pull force values that can be used to set force limits that will contribute to protecting worker health and safety and insuring manufacturing quality.

1. Introduction

Work related musculoskeletal disorders continue to be a major concern as injury rates continue to plague the workplace. Many of these injuries are sustained by the hands and wrists and a number of efforts have been made to increase our understanding of the tolerance of the hand to withstand loading without injury. Psychophysical studies have established maximum acceptable loads for wrist ulnar deviation (Ciriello et al., 2001, 2002), wrist flexion and extension with various grips (Snook et al., 1995, 1999; Ciriello et al., 2001), hand grips (Dahalan and Fernandez, 1993; Ciriello et al., 2001, 2002), drilling tasks (Kim and Fernandez, 1993; Marley and Fernandez, 1995), hand impacts (Potvin et al., 2000), electrical connector mating (Potvin et al., 2006) and hose insertions (Andrews et al., 2008).

In manual manufacturing tasks, the fingers are very often used to push, pull and manipulate objects such as fasteners and clips. In spite of this, little data exists to indicate the capacity of the fingers (single and multi-analysis) for pushing and pulling tasks. Currently, most of the push and pull strength literature has focused on the determining hand strength under various conditions; including upper limb posture and end-effector (such as fastener, clips and end-connectors) height. Specifically, Kumar (1995) and Cheng and Lee (2004) examined pulling strength at various handle heights, and MacKinnon (1998) studied the same variable but while standing and sitting. In addition, Fothergill et al. (1996) investigated how the end-effector in combination with height influenced overall pull strength. However, it must be noted that the aforementioned studies all investigated pull strengths while the hand maintained a power grip posture or included a pinch grip technique while pulling. Additionally, maximum push data have been presented for the finger pad and thumb by Nussbaum and Johnson (2002) and Peebles and Norris (2003) and for the thumb tip by Longo et al. (2002). Yet, very little is known about the capacity for the fingers to exert pulling forces.

Imrhan and Sundararajan (1992) did study finger pull strength, however, the results from this study apply only to tasks that include finger pinches while pulling. As previously mentioned, there are a number of manufacturing tasks that require the finger(s) to be used as a tool to hook and pull various parts. To our knowledge, DiDomenico and Nussbaum (2003) have conducted one of the only studies of finger pulling, but that study was limited to pulling with only one finger. The purpose of the current study was to determine maximum finger pull forces for a variety of conditions that do not involve pinches and have not been presented previously in the literature. It is expected that these data will contribute to our growing understanding of the capacity of the hand to do work so that manufacturing tasks can be designed with a reduced risk of hand injury.

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