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COMMENTARIES

Are Two Hands Sensing the Load Better Than One?

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The target article sets an important framework for revisiting the current theoretical and experimental approaches to motor control of the hand function and provides a background for their application to patient populations.

A prerequisite for the elaborate use of the human hand during manipulation of objects is the ability to produce, maintain, and regulate grip force. Successful object manipulations are based on the application of forces that are large enough to prevent slips but are not excessive preventing fatigue and damage of the lifted object. Thus, appropriate regulation of grip force is essential to perform various activities of daily living such as drinking, eating, buttoning a shirt, etc. In addition, proper modulation of grip force is crucial for the performance of a number of work-related activities (Bell-Krotoski, 1991; Gilles & Wing, 2003; Nowak & Hermsdorfer, 2004).

Humans usually apply grip force above the slippage threshold so there is a safety margin (Johansson & Westling 1984) needed to generate sufficient friction between the digit tips and the object surface; as a result, the grip force is higher than the minimal value required to avoid slippage of the objects. The capability to scale grip forces to lift an object depends on many factors such as age, gender, handedness, etc., and it changes with age and disease (Gilles & Wing, 2003; Nowak & Hermsdorfer, 2004). Thus, elderly persons apply larger grip forces to manipulate an object as compared with younger individuals (Cole & Rotella, 2002; Gilles & Wing, 2003). In addition, individuals with stroke, cerebellar disorders, cerebral palsy and impaired tactile sensibility commonly produce inefficiently elevated grip forces while performing simple daily tasks (Gordon & Duff, 1999; Hermsdorfer, Hagl, Nowak, & Marquardt, 2003; Nowak, Glasauer, & Hermsdorfer, 2003). It was also reported that patients with multiple sclerosis (MS) applied larger forces in comparison with healthy subjects while performing static bimanual tasks (Marwaha, Hall, Knight, & Jaric, 2006) and while lifting and transporting a hand-held object (Iyengar, Santos, Ko, & Aruin, 2009b).

Surprisingly, most of available information about the regulation of grip force was obtained from the studies focused on single-hand tasks, particularly simple grip and lift tasks performed by the dominant hand (Diermayr, McIsaac, & Gordon, 2011; Flanagan & Tresilian, 1994). However, many tasks humans perform using

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both the hands. This requires an even more efficient control by the brain and prompted investigations of the bimanual hand function (Gorniak, Zatsiorsky, & Latash, 2007; Jaric, Collins, Marwaha, & Russell, 2006; Krishnan & Jaric, 2010).

In particular, it was described that the grip force was reduced when a supporting force is provided by the other hand that helps keep the load against gravity (Scholz & Latash, 1998). It was also shown that the magnitude of grip force used to lift and transport a hand-held object decreased if a light touch from the contralateral finger was provided to the wrist of the target arm (Aruin, 2005). The reduction of grip force in conditions with the light touch from the contralateral finger is associated with using smaller safety margins, which could be explained by several factors. First, the information from the proprioceptive and joint position sense receptors of the contralateral arm is used together with information obtained from the arm that is performing the lifting task. This could enhance the sensorial input allowing better modulation of grip force (Aruin, 2005; Nowak et al., 2001). Second, it has been shown that light finger touch could provide spatial cues, which, similarly to vision, could enhance the control of position of the body segments in space (Jeka & Lackner, 1994; Lackner, Rabin, & DiZio, 2001). Third, this could be the effect of subjective feeling that one hand is supporting the other (even no physical support is provided), thus helping in the reduction of grip force. While results supporting this suggestion are not available at the moment, subjects reported that it was much easier to accomplish the experimental task with the application of a light touch compared with no-touch conditions (Iyengar, Santos, Ko, & Aruin, 2009a).

Subsequent studies involving healthy individuals were conducted to confirm that the observed finger touch-related decrease in grip force is not associated with experimental artifacts. For example, smaller grip force could be due to slower lifting an object when a finger touch is provided as compared with lifting with no touch. It was shown that the finger touch-related decrease in the grip force was seen across all task velocities suggesting that the minimization of grip force when a finger touch is provided is not associated with possible slowness of the movement of the target arm (Iyengar, Santos, & Aruin, 2009). Moreover, it was reported that within the same arm movement velocity, the reduction in grip force with the touch by the contralateral finger was not associated with a specific location of the touch point on the forearm as grip force was reduced by approximately the same amount in all conditions with the finger touch compared with the no-touch condition (Iyengar, Santos, & Aruin, 2009). The explanation to this experimental finding was that since finger touch involved movements of the contralateral arm in all conditions, the decrease of grip force was due to the information from muscles and joint receptors of the contralateral arm used together with the information from the receptors of the target arm thus allowing more efficient modulation of grip force (Aruin & Kamdar, 2005; Iyengar, Santos, & Aruin, 2007). This finding was challenged in the subsequent study when the index finger touch of the contralateral arm was provided to the wrist, elbow, and shoulder. Touching the wrist and elbow involved movements of the contralateral arm; no movements were produced while touching the shoulder. Grip force was reduced by approximately the same amount in all conditions with the finger touch compared with the no-touch condition. This suggests that information from the muscle and joint receptors of the contralateral arm is used in the control of grip force when a finger touch is provided to the wrist and elbow, and cutaneous information is used when lifting an object while touching the shoulder (Chen & Aruin, 2013). The results of these studies provide additional evidence to support the use of both arms in the performance of activities of daily living.

The contribution of the finger touch to the modulation of grip force was tested in individuals with stroke, multiple sclerosis (MS) and the elderly. In particular, it was demonstrated that individuals with stroke could significantly reduce grip force during lifting and transporting an object when a light finger touch from the contralateral arm was provided to the target arm (Aruin, 2005). A similar decrease in the grip force was observed in individuals with MS performing two functional tasks. The first task, *placing task*, was a lifting and placing the object on a shelf. The second task, *drinking task*, was a simulation of the movement of drinking water from a cup that included lifting the cup and moving it close to the mouth. These two tasks were performed with and without the provision of a light contralateral finger touch to the wrist of the target hand. The outcome of the study revealed that mildly involved individuals with MS reduced grip force by 19% when a touch from the contralateral finger to the wrist of the target arm was available (Iyengar, Santos et al., 2009a). This potentially could help such individuals to reduce the grip force production, which might lead to a delay in the onset of fatigue and decrease the susceptibility to musculoskeletal injuries.

I cannot agree more with Mark Latash that "we know very little about the brain control of the hand" (Latash, 2015). However, exploring new approaches to optimize control of grip force could potentially provide answers to a number of important questions thus bringing us closer to complete understanding of how the hand works.

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