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Original

The force used to pick up an object with one upper extremity after picking up a heavy object contralaterally

—— Does the force in the non-dominant hand for picking up an object influence the force in the dominant hand? ——

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Abstract

This study follows the two studies "Generation of excess grip force after picking up a heavier object with the contralateral hand" by Noda (2004) and "The force used to pick up an object with one upper extremity after picking up a heavy object contralaterally: The influence of the force for the unilateral picking up of an object on the force used on the opposite side," by Nagai et al. (2010). In Noda (2004) and Nagai et al. (2010), the procedures of picking up an object first with the dominant hand and then by the non-dominant hand was used. In our study, we used the same procedures but in reverse order, so as to investigate the influence of the non-dominant hand on the dominant hand. Results showed that the surface pressure did not significantly increase when picking up a light object with the dominant hand after picking up a heavy object with the non-dominant hand. This result was different from the those reported by Noda (2004) and Nagai et al. (2010).

Key words: precision grip, information on the weight, dominant hand, non-dominant hand, contact surface pressure

Introduction

One of the important functions of the hands in activities of daily living is adjusting to environmental changes (Nakamura and Sawada, 1993). People change the shape of their hands based on the shape of objects. They also change the power used for picking up and gripping according to the weight of objects. These functions enable people to lead their daily lives without difficulty. There are various studies (Noda, 2004; Nagai et al. 2010; Nakamura et al. 1993; Gordon et al. 1991; Gordon et al. 1991; Gordon et al. 1991; Kawai et al. 1994; Kawai et al. 1995; Kawai et al. 1997; Mon-Williams et al. 2000; Kawai et al. 2001; Sambuichi and Katayama, 2001; Westling and Johansson, 1984; Johansson and Westling, 1984; McCloskey, 1974; Kotani et al. 2002; Ardila et al. 1987; Nakamura and Sawada, 2004) on precision grip, which is the motion to pick up an object with the thumb and index finger. The processing mechanism of the precision grip in the brain has also been investigated and reported (Kinoshita et al. 2002; Takei and Seki; 2008). It has been clarified that the force applied in a precision grip is influenced by the physical characteristics of condition of the surface, weight, and size; and by the physiological characteristics of psychological condition and age of the person who performs the motion (Gordon et al. 1991; Gordon et al. 1991; Gordon et al. 1991; Kawai et al. 1994; Kawai et al. 1995; Kawai et al. 1997; Mon-Williams et al. 2000; Kawai et al. 2001). Kawai et al. (2001) reported that information on an object's size obtained through vision could influence the output program in generating the force to pick up an object. The study explained that the

force applied to pick up an object was dependent on the object's size as assessed by vision. Sambuichi et al. (2001) also stated that the force for grasping was planned and generated taking into consideration the dynamic characteristics of the object.

In the study by Westling and Johansson (1984), the force was divided into two types: one was Slip Force, which was defined as the minimum power to hold an object, and the other was Safety Margin Force, the force to prevent a sudden fall while holding the object. Slip Force can be determined based on the physiological characteristics of the object, especially the smoothness of the surface. Safety Margin Force is influenced by the voluntary intention of a person. Kawai et al. (1995) reported that Safety Margin Force increased significantly when the gripping surface changed unexpectedly. However, the study also reported that change in the surface condition and the weight of objects influenced Slip Force and Safety Margin Force, and both increased along with the smoothness of the gripping surface. Therefore we expected that results of measuring the force applied on the surface of the object would reflect the change of the reaction in the brain.

From the findings cited (Kawai et al. 1995; Westling and Johansson, 1984) it is clear that information on the physical characteristics of objects is recorded during unilateral precision grip and that it influences any precision grip that follows on the same side. However, there is still a question of whether unilateral-grip information on the physical characteristics of an object influences precision grip on the opposite side. Noda (2004) and Nagai et al. (2010), looking at contact surface pressure, reported that weight information on precision grip on one side influences precision grip on the opposite side when employing heavy and light weights with the same appearance. Results showed that after picking up a heavy weight on one side, an excessive contact surface pressure was applied on the opposite side for a light weight. Therefore, information on weight from a precision grip on one side was stored as data in the brain and affected a following precision grip on the other side.

With the consideration of dominant and non-dominant hand, the procedure used by Noda (2004) and Nagai et al. (2010) clarified that the movement conducted by the dominant hand influenced the movement of the non-dominant hand when picking up a heavy object with dominant hand was first followed by picking up a light object with non-dominant hand. However, the case of the reverse order has not been clear. Therefore, in this study we adopted the order of picking up a heavy object with the non-dominant hand followed by picking up a light object with the dominant hand. By using objects of different weights, this research seeks to clarify the influence of movement by the non-dominant hand on the dominant hand.

Methods

1. Subjects

The subjects were 14 healthy people (7 males and 7 females), with a mean age of 20.9±0.3 years, with no superficial nor deep sensation deficits. All subjects were right handed when pitching a baseball, using scissors or chopsticks, and writing.

2. Measurement units

Figure 1 shows the object for gripping used in the experiment. The upper part of the object was pinched and lifted with a palmar pinch between the thumb and index finger. The object's weight could be adjusted by removing weights from the bottom. The force of the precision grip was measured as the contact surface pressure by using two air-packs (Air-pack type contact surface pressure measuring system, AMI TECHNO) of 11×17 mm. The two air-packs were attached to the contact surfaces of the upper part of the grip object which were to be grasped by the thumb and index finger. To measure the contact surface pressure, the air-pack type contact surface pressure measuring system AMI 3037-2 (AMI TECHNO) was used. Then, the contact surface pressure signal was converted from analog to

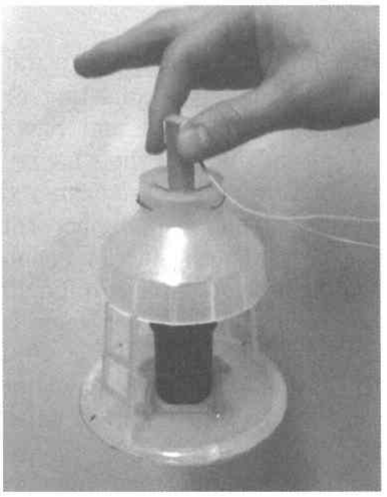

Figure 1 Object to be picked up with a palmar pinch of the thumb and index finger

digital using Power Lab 16 sp (AD Instruments). The sampling frequency was 10 Hz. Data were stored using Chart v. 4. 1. 2 (AD Instruments) with a PC. The weights placed under the object for gripping were of two types: a 301.0-g black film container (heavy film container) which contained a lead weight and was sealed, and a 7.5-g black film container (light film container) which contained nothing and was also sealed. These two different containers had identical appearances, and gave no visual cues regarding weight.

3. Experimental procedures

The experiment was conducted as follows:

1) The subject sat down in front of a desk, and the height of the desk was adjusted to the same height as the position of the forearm when flexing the elbow joint at 90 degrees. The chair was positioned from the desk at the distance of one fist-width (approximately 10 cm) when the subject was sitting. The object for gripping and chair were arranged in a median frontal configuration.

2) The experimental procedure was explained to the subjects verbally, and they practiced the procedure once for the left side and once for the right side with the light film container. We did not warn the subject of the possibility that the weight of the object may change.

3) The subjects were instructed to pick up the object with a palmar pinch using the thumb and its index finger and to hold it for approximately 10 seconds, and then to put the object down in its original place. The subject was also instructed to pick up the object with a minimum of grip force and not to use any digits other than the thumb and index finger. To measure the movement under a more natural condition, instructions were not given during the course of the motion. Subjects were allowed to pick up the object at their own pace, and they could leave the object anywhere during rest.

4) The first trial was performed using the left hand, followed by the right hand. After the first set of measurements, the subject was assigned a 5-minute task unrelated to the experiment in order to allow the memory of the weight sensation to grow dull. The task was a creative task: making a 1-story house using toy blocks (Duplo). The experiments proceeded as follows: experiment 1 (grip force), the unrelated task for 5 minutes (blocks), then experiment 2 (grip force), the unrelated task for 5 minutes (blocks), and experiment 3 (grip force) (Figure 2).

5) There were three types of condition involving light and heavy objects.

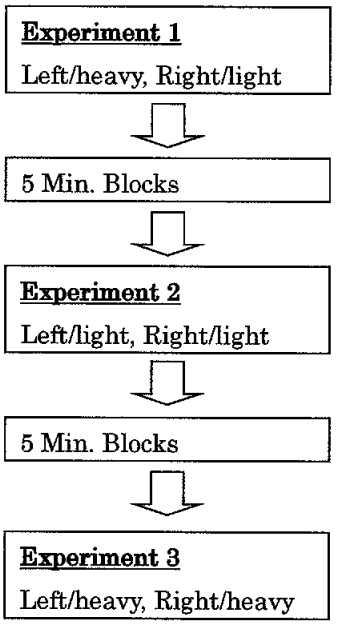

Figure 2 Experimental procedures Experiments 1, 2, and 3 were assigned at random

Condition 1: Pick up the heavy object with the left hand and then pick up the light object with the right hand (Left/heavy, Right/light).
Condition 2: Pick up the light object with the left hand and then pick up the light object with the right hand (Left/light, Right/light).
Condition 3: Pick up the heavy object with the left hand and then pick up the heavy object with the right hand (Left/heavy, Right/heavy).

To reduce any influence from the sequence order, conditions 1, 2, and 3 were assigned at random.

6) The object for gripping was covered by a screen, and the weight of the object was changed every trial to prevent the subjects from predicting its weight by observing it.

4. Analysis method

The average contact surface pressure of the thumb and index finger measured by the two air-packs was designated as the contact surface pressure obtained from the experiment. The peak values of the contact surface pressure from the left and right fingers under each condition were compared and analyzed. Paired t-tests were used to evaluate differences between the contact surface pressures of conditions 1, 2, and 3. The level of significance was set at 0.01. Statistical software Statcel (OMS publishing Inc.) was used for analysis.

Table 1 Comparison between contact surface pressure (CSP) of right hand under conditions 1 and 2, and comparison between CSP of left hand under conditions 1 and 3

Condition	Condition 1	Condition 2	Condition 1	Condition 3
	Right/light	Right/light	Left/heavy	Left/heavy
CSP (kPa)	0.53±0.16	0.51±0.13	1.51±0.22	1.56±0.30
p-value	0.653		0.449	
S. S.	N. S.		N. S.	

S. S.: Significance, N. S.: No significance

Results

1) Comparison among conditions 1, 2, and 3.

In condition 1, the contact surface pressure of the right hand when picking up the light object was 0.53±0.16 kPa, whereas, in condition 2, the contact surface pressure for picking up the light object with the right hand when was 0.51±0.13 kPa. No significant difference was observed between them (Table 1). The contact surface pressure of the right hand after picking up the heavy object with the left hand was not higher than that of the measured pressure after picking up the light object with the left hand.

2) Comparison within the same condition.

The contact surface pressure of the left and the right hands when picking up either a light or heavy object were compared. The contact surface pressures under condition 1 (the heavy object picked up with the left hand and the light object picked up with the right hand) were 1.51±0.22 and 0.53±0.16 kPa, respectively, showing a significant difference between them ($p<0.01$). The contact surface pressures under condition 2 (the light object picked up with the left hand and the same light object picked up with the right hand) were 0.61±0.32 and 0.51±0.13 kPa, respectively. No significant difference was observed between them. The contact surface pressures under condition 3 (the heavy object picked up with the left hand and the same heavy object picked up with the right hand) were 1.56±0.30 and 1.56±0.26 kPa, respectively. No significant difference was observed between them (Table 2).

Discussion

Comparison of the contact surface pressures of the right hand between conditions 1 and 2 showed that the pressure was not significantly different. This result was not consistent with Noda's (2004) and Nagai et al.'s (2010) studies. The difference in the procedure between conditions 1 and 2 was the weight of the object picked up with the left hand before picking up the light object with the right hand. This implies that the experience of picking up the heavy object with the left hand did not influence the same motion subsequently conducted with the right hand.

Johansson and Westling (1984) and McCloskey (1974) have reported on precision grip movement in humans, saying that grip force is exerted according to the weight. They state that the weight sensation memorized during the motion of picking up an object strongly affects the grip force of the subsequent picking up motion. Our results were not consistent with theirs.

Kotani (2002) clarified the mechanism how information of the weight was shared between both hands within the brain and used for control on producing a voluntary force. However, the results from this study suggest that the weight sensation of the non-dominant hand might not be shared with the dominant hand.

We would also like to look at the results within each condition. There was no significant difference in contact surface pressure between the left and right hands within each condition. Comparing conditions 2 and 3, there was no significant difference in the contact surface pressure between left and right hands. However, the contact surface pressure of the left hand was significantly higher than for the right in condition 1. In condition 1, the heavy object was picked up with the left hand, followed by picking up the light object. In condition 2, the light objects were picked up with the left and the right hands. In condition 3, the heavy objects were picked up with the left and the right hands. In condition 1, the

Table 2 Contact surface pressure (CSP) of left and right hands under 3 conditions

Condition	Condition 1		Condition 2		Condition 3	
	Left/heavy	Right/light	Left/light	Right/light	Left/heavy	Right/heavy
CSP (kPa)	1.51±0.22	0.53±0.16	0.61±0.32	0.51±0.13	1.56±0.30	1.56±0.26
p-value	1.37E-10		0.266		0.957	
S. S.	*		N. S.		N. S.	

S. S.: Significance, *: $p<0.01$, N. S.: No significance

weight of the objects was different for the left and the right hands. This difference may have led to the differences in contact surface pressure between left and right hands. This result also agree with Noda's study (2004) and Nagai et al.'s study (2010). In conditions 2 and 3, which did not involve different weights, there was no difference in the contact surface pressure between the two hands. These results also agreed with Noda's study (2004) and Nagai et al.'s study (2010).

Ardila et al. (1987) reported that the function of the sensation of the weight in the dominant hand was more precise than in the non-dominant hand. Therefore, it would be possible to grip more precisely and control gripping more accurately when holding an object with the dominant hand. Noda (2004) and Nagai et al. (2010) had concluded that the power for picking up a heavy object with the dominant hand influenced the power for picking up a light object with non-dominant hand because of a superior weight sensation in the dominant hand.

In this study it was suggested that the sensation of weight in non-dominant hand might not be shared between left and right hemispheres in the brain. Further data are needed to obtain more reliable results. We would like to investigate whether improving the function of the weight sensation in the non-dominant hand would enable sharing the sensation with the dominant hand.

Conclusion

We conducted this study with fourteen healthy people, employing a procedure different from Noda's (2004) and Nagai et al.'s (2010). The results showed that information on weight during the left-hand (non-dominant hand) trial did not influence the right-hand (dominant hand) trial when picking up a heavy object with the left hand was followed by picking up a light object with the right hand.

References

Ardila A, Uribe BE, Angel ME: Handedness and psychophysics: Weight and roughness, Int. J. Neuroscience 36: 17-21, 1987

Gordon AM, Forssberg H, Johansson RS, Westling G: Visual size cues in the programming of manipulative forces during precision grip. Exp. Brain Res 83: 477-482, 1991

Gordon AM, Forssberg H, Johansson RS, Westling G: The integration of haptically acquired size information in the programming of precision grip. Exp. Brain Res 83: 483-488, 1991

Gordon AM, Forssberg H, Johansson RS, Westling G: Integration of sensory information during the programming of precision grip: comments on the contributions of size cues. Exp. Brain Res 85: 226-229, 1991

Johansson RS, Westling G: Roles of glabrous skin receptors and sensorimotor memory in automatic control of precision grip when picking up rougher or more slippery objects. Exp. Brain Res 56: 550-564, 1984

Kawai S, Kinoshita H, Ikuta K: Effects of object weight on the regulation of static grip forces during holding tasks using a precision grip. J. Phys. Fitness Sport Med 43: 247-258, 1994

Kawai S, Kinoshita H, Ikuta K, Yamamoto T: Effects of varied surface condition on regulation of grip force during holding tasks using a precision grip. J. Phys. Fitness Sport Med 44: 519-530, 1995

Kawai S, Tsuda H, Kinoshita H, Ikuta K, Hashizume K, Murase T, Yamamoto T: Effects of aging on force adaptation during manipulation of a small object using a precision grip. J. Phys. Fitness Sport Med 46: 501-512, 1997

Kawai S, Ikuta K, Yamamoto T: Effects of visually perceived size on force control while manipulating small objects with a precision grip. J. Phys. Fitness Sport Med 50: 513-520, 2001

Kinoshita H, Aoki T, Tsuda H, Oku N, Hashikawa K: Pet studies of human cortical and subcortical systems involved in lifting tasks with a precision grip. J. Biomechanisms 16: 101-113, 2002

Kotani K, Lee S, Horii K: Empirical study on control characteristics of the grip force during coordinated bimanual arm movement. Japanese Journal of Physical Anthropology 7: 115-121, 2002

McCloskey DI: Muscular and cutaneous mechanisms in the estimation of the weights of grasped objects. Neuropsychologia 12: 513-520, 1974

Mon-Williams M, Murray A H: The size of the visual size cue used for programming manipulative force during precision grip. Exp. Brain Res 135: 405-410, 2000

Nagai E, Matsuya A, Yoshii C, Yoshida M: The force used to pick up an object with one upper extremity after picking up a heavy object contralaterally: The influence of the force for the unilateral picking up of an object on the force used on the opposite side. Aino journal 9: 15-19, 2010

Nakamura M, Sawada Y: The influence of load force perturbation on the control of precision grip during lifting tasks. Occupational Therapy 12: 259-268, 1993

Nakamura M, Sawada Y: Fundamental movement patterns and function of the human hand. Bull. Sch. Hlth. Sci. SapporoMed. Univ 7: 5-9, 2004

Noda K: Generation of excess grip force after picking up a heavier object with the contralateral hand. Bulletin of Health Sciences Kobe 20: 29-35, 2004

Sambuichi EM, Katayama M: A grip force generation mechanism for object manipulation using a precision grip. IEICE Technical Report, MBE 100(685): 41-48, 2001

Takei T, Seki K: Neural control of primate grasping —A new function of spinal interneuons—. IEICE Technical Report, HIP 108(282): 101-105, 2008

Westling G, Johansson RS: Factors influencing the force control during precision grip. Exp. Brain Res 53: 277-284, 1984