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Original

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 ——

Eiichi NAGAI — *Professor, Department of Occupational Therapy, Faculty of Nursing and Rehabilitation, Aino University*

Ayako MATSUYA — *Assistant professor, Department of Physical Therapy, Faculty of Nursing and Rehabilitation, Konan Women's University*

Chihiro YOSHII — *Student, Department of Occupational Therapy, Faculty of Nursing and Rehabilitation, Aino University*

Masaki YOSHIDA — *Professor, Department of Physical Therapy, Faculty of Biomedical Engineering, Osaka Electro-Communication University*

Abstract

This research is a re-investigation of the "Generation of excess grip force after picking up a heavier object with the contralateral hand" which was conducted by Noda [1]. Noda [1] reported that information on the weight when picking up an object with the thumb and index finger influences information on the weight when picking up an object with the contralateral arm. The results we obtained in this study agreed with Noda's study [1]. From our study, we confirmed that information on the weight of objects when picking up influenced information on the weight when picking up an object on the opposite side.

Key words: precision grip, information on the weight, contact surface pressure

Introduction

One of the important functions of the hands in activities of daily living (ADL) is adjusting to environmental changes [2]. People change the shape of their hands based on the shape of objects. They also change the power for the picking up and gripping according to the weight of objects. As a result of these functions, people are able to lead their daily lives without any difficulty. There are various studies [1-18] on precision grip, which is the motion to pick up an object with the thumb and index finger. It is clarified that the force applied in the precision grip is influenced by the physical characteristics: condition of the surface, weight, and size, and physiological characteristics: psychological condition and the age of the person who performs the motion [3-10]. Kawai [10] 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 size assessed by vision. Sambuichi et al. [11] also started that the force for grasping was planned and generated with consideration of the dynamic characteristics of the object.

In the study by Westling and Johansson [12], 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, which was defined as 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 defined as the force influenced by the voluntary intention of a person. Kawai [7] reported that the change in the surface condition and weight of objects influenced Slip Force and Safety Margin

Force, and both increased along with the smoothness of the gripping surface. The study also reported that Safety Margin Force significantly increased when the gripping surface changed unexpectedly. As for these findings, it is clear that information on the physical characteristics of objects is recorded during unilateral precision grip and influence the following precision grip on the same side. However, there is still a question of whether information on the physical characteristics of an object on unilateral grip influences precision grip on the opposite side. Noda [1] reported that information on the weight on precision grip on one side influences precision grip on the opposite side on employing heavy and light weights with the same appearance. In the same study, it was also reported that, after picking up a heavy weight on one side, an excessive contact surface pressure was produced on the opposite side when using a light weight. In other words, information on the weight from the precision grip on one side was recorded and affected the following precision grip on the other side. We could not identify research other than that of Noda [1] which clarified that information on the physical characteristics of an object on unilateral precision grip influenced the following precision grip on the other side. This led us to conduct this study with the purpose of clarifying validity and reliability of the study conducted Noda [1] using the same procedure.

Methods

1. Subjects

The subjects were 12 healthy females, with a mean age of 20.8±0.5 years, with no superficial and no 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 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 contact surfaces of the thumb and index finger of the upper part of the grip object. For measurements of 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 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 in regard to the weight.

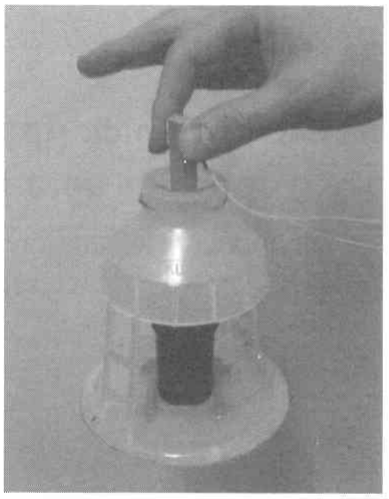

Figure 1 Object to be picked up with a palmar pinch of the thumb and index finger

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 each left and right sides 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 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

original place. The subject was also instructed to pick up the object with the minimum 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 right hand, followed by the left hand. After the first set of measurements, the subject was assigned a task which was unrelated to the experiment for 5 minutes in order to dull the memory of the weight sensation. The task was a creative task: making a 1-story house using toy blocks (Duplo). The experiments proceeded as: 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.

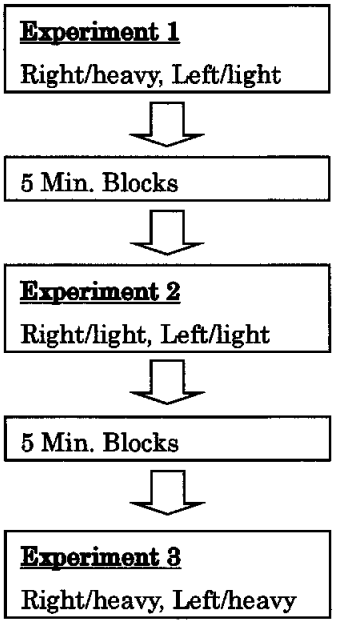

Figure 2 Experimental procedures Experiments 1, 2, and 3 were assigned at random

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

Results

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

In condition 1, the contact surface pressure of the left hand when picking up the light object was 0.84±0.32 kPa. On the other hand, in condition 2, the contact surface pressure of the left hand when picking up the light object was 0.61±0.17 kPa. There was a significant difference ($p<0.01$) between conditions 1 and 2 (Table 1). The contact surface pressure of the left hand after picking up the heavy object with the right hand was higher than that of the measured pressure after picking up the light object with the right hand.

Table 1 Comparison between contact surface pressure (CSP) of the right under condition1 and 2, and comparison between CSP of left hands under conditions 1 and 3

Condition	Condition 1	Condition 2	Condition 1	Condition 3
	Left/light	Left/light	Right/heavy	Right/heavy
CSP (kPa)	0.84±0.32	0.61±0.17	1.14±0.16	1.12±0.15
p-value	0.004		0.239	
S. S.	*		N. S.	

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

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

Condition	Condition 1		Condition 2		Condition 3	
	Right/heavy	Left/light	Right/light	Left/light	Right/heavy	Left/heavy
CSP (kPa)	1.14±0.16	0.84±0.32	0.67±0.27	0.61±0.17	1.12±0.15	1.18±0.15
p-value	0.006		0.169		0.942	
S. S.	*		N. S.		N. S.	

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

2) Comparison within the same condition.

The contact surface pressure of the left and right hands were compared when picking up either a light or heavy object. The contact surface pressures under condition 1, the heavy object picked up with the right hand and the light object picked up with the left hand, were 1.14±0.16 and 0.84±0.32 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 right hand and the same light object picked up with the left hand, were 0.67±0.27 and 0.61±0.17 kPa, respectively. No significant difference was observed between them. The contact surface pressures under condition 3, the heavy object picked up with the right hand and the same heavy object picked up with the left hand, were 1.12±0.15 and 1.18±0.15 kPa, respectively. No significant difference was observed between them (Table 2).

Discussion

Comparison of the contact surface pressures of the left hand between conditions 1 and 2 showed that the pressure was significantly higher in condition 1. This result was consistent with Noda's study [1]. The difference in the procedure between conditions 1 and 2 was the weight of the object picked up with the right hand before picking up the light object with the left hand. This implies that the experience of picking up the heavy object with the right hand influenced the subsequent picking up motion with the left hand. The results of conditions 2 and 3 showed that a high contact surface pressure was generated when picking up a heavy object in condition 2 and a low contact surface pressure was generated when picking up a light object in condition 3. These results suggest that the sensation of picking up an object on one side leads to the production of an excessive force on the opposite side when picking up a light object.

Johansson and Westling [13] and McCloskey [14] have reported on precision grip movement in humans, and that grip force is exerted according to the weight. They stated that the weight sensation memorized during the motion of picking up an object strongly affected the grip force of the subsequent picking up motion. The results obtained in our study were consistent with their studies. Kawai [7] reported that, during unilateral precision grip, the change of the grip surface and weight of the object influenced the Slip Force and Safety Margin Force. Their results showed that both Slip Force and Safety Margin Force elevated along with an increase in the smoothness of the grip surface. Moreover, they reported that an unexpected change in the grip surface resulted in a significant increase in Safety Margin Force.

The results showed that a change in the weight may lead to a significant increase in Safety Margin Force because the grip surface did not change. Kotani [15] clarified the mechanism whereby information on the weight was shared between both hands within the brain and used for control on producing a voluntary force. From this study, we understood that the dominant hand for conducting a motion might have a less marked relationship on sharing the sensation of the weight between both hands. The subjects were all right-handed. Also, the hand used to naturally pick up the object was the right (dominant hand). Although we did not confirm whether the sensation of the weight was shared between both hands and the dominant hand was related to the shared sensation, we would like to conduct a study employing the same procedure with left-handed people, or investigate it with the added condition of picking up the object with the left hand first.

We will discuss the difference in contact surface pressure between the left and right hands under each condition. There was no significant difference between the contact surface pressure for both hands in conditions 2 and 3. However, the contact surface pressure of the right hand was significantly higher than for the left in condition 1. In condition 1, the heavy object was picked up with the right hand, followed by picking up the light object. In condition 2, the light objects were picked up with the right and left hands. In condition 3, the heavy objects were picked up with

the right and left hands. In condition 1, the weight of the objects was different for the right and left hands. This difference may have led to the differences in contact surface pressure between right and left hands. In conditions 2 and 3, which did not involve different weights, there was no difference in the contact surface pressure between both hands. These results also agreed with Noda's study [1].

One of the important functions of the hands is adaptation to changes in the environment when using them in ADL. A person usually changes the shape of the hands depending on the shape of objects. The power of the pinch and grasp is controlled regarding the weight of objects. Therefore, a person can live without having any difficulty in daily living. We would like to think about functional recovery of the hands for people with disturbance of pinching and grasping based on the results of our research and Noda's [1]. There are many patients with paralysis of their upper extremities, whereby the function to control the physical character of objects has been disturbed on pinching and grasping even though the paralysis is not severe [16]. For such cases, we think that the practice of picking up an object with the same appearance and different weight would be effective, a technique that Noda [1] and ourselves adopted. The practice of picking up objects which have different surface characteristics but the same weight or objects which are different sizes but the same weight would also be effective, as reported in the literature [3-10]. Today, more new evidence is being accumulated regarding the brain mechanism for precision grip [17, 18], and further study of precision grip based on the brain mechanism is needed.

Conclusion

We conducted this study employing the same procedure as Noda [1] involving twelve healthy women. The results showed that information on the weight during the right-hand trial influenced the left-hand trial when picking up a heavy object with the right hand followed by picking up a light object with the left hand,

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