Influence of changing contact area of index finger pushing force on force accuracy

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Key words：Index finger, Pushing force, Force accuracy

Abstract

Introduction: Treatment programs for occupational therapy are adapted for patients with upper-limb paralysis and finger injuries. To improve the movement accuracy when executing these treatment programs, it is important to investigate the effects of movement output by repetitive training as standards of an acquisition of correct movement. The purpose of this study is to examine the influence of changing the contact area of the index finger pushing force on force accuracy.

Method: Subjects reproduced a push force identical to a target force under a large contact area and under a tiny contact area, after repeating the target force. We explained the purpose of the experiment, and all subjects provided written informed consent prior to participating in the study.

Results: There were no significant differences between the large and tiny contact groups.

Discussion: The size of the contact area when using only tactile senses does not influence the accuracy of the pushing force. We propose important information regarding the contact area and force accuracy of the index finger for selecting the appropriate occupational therapy treatment programs.

1. Introduction

Rehabilitation has been executed continuously from the early stage of a disorder for the paralysis of the upper limbs after stroke, or for injuries to fingers due to an accident. Rehabilitation also contributes to improvements in a patient's skills for basic movement or activities of daily living (ADL) [1)].

In occupational therapy, programs to treat paralysis of or injury to the upper limbs or fingers are performed by means of woodworking, metalworking, crafting, and so on. Through application of these treatment programs, it is possible for patients to regain movements or actions, such as gripping, separating, pushing, and holding objects, as well as writing, cooking, and dressing[2)]. Therefore, to improve movement accuracy when conducting these programs[3)], it is necessary to investigate the effects of movement output by repetitive training as standards for acquisition of the correct movement[4-8)].

However, previous studies have only investigated the use of multiple fingers, and analyzed the results from the perspective of engineering sciences[9-12)]. Therefore, for treatment that is part of occupational therapy, it is necessary to pay closer attention to the relationship between the fingertips and objects.

The purpose of this study is to examine the effect of force accuracy on the pushing force at the index finger by changing the contact area and to investigate the influence of the size of the contact area.

2. Materials and Methods

2.1. Subjects

Subjects were divided into two groups according to the pushing force at the index finger: a large contact area group and a tiny contact area group. The large contact area group included eight male and two female university students aged 20 ± 0.47 (mean ± SD) yr. The tiny contact area group included nine female

university students aged 19.56 ± 0.53 yr. All subjects were right-handed, and had no known history of musculoskeletal or neurological disorders. All subjects received an explanation of the purpose of the experiment and provided signed informed consent before participation.

2.2. Procedure

To maintain constant friction between the tip of the index finger and the press board, subjects washed their right hand for 20 s or more before the experiment.
The subject sat on a chair in front of the device (Fig. 1), and then placed his or her index finger on the press board at a height of 350 mm, as shown in Fig. 2.

To obtain the force value, the target push forces were 100 g, 200 g, and 300 g. The subject, with closed eyes, repeated the target push force ten times in conjunction with the motion of the servo motor. After repeating the target force, the subject was instructed to push the press board at the same value of the target force to reproduce the force, and to maintain this push force for 15 s.

Data were recorded when the force exceeded 20 g. We defined three periods of the experiment as follows: the first period was 0.00–5.00 s, the second period was 5.01–10.00 s, and the third period was 10.01–15.00 s. The force signals were digitized at a rate of 500 samples per second.

The force data during a 15 s arm hold were defined as the mean force.

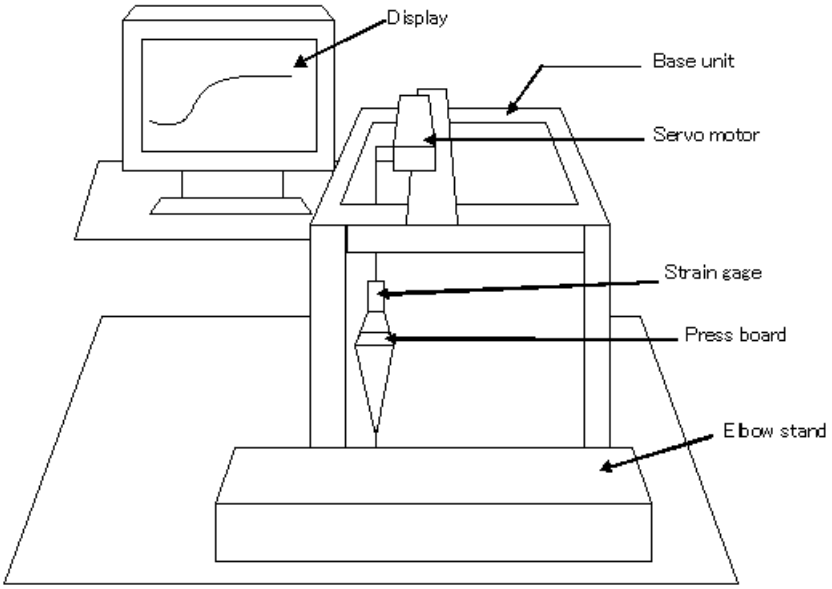

Figure 1. Device for the measurement of the push force.

2.3. Data analysis

The error of the target force was defined as a constant error: measured force minus the target force. The mean of the constant error was analyzed by two-way analysis of variance (ANOVA). Post-hoc analysis was performed using the Bonferroni procedure. Statistical significance was defined at the $p < 0.01$ level. Statistical analysis of all data was performed using Statpartner V4.5 (O-ha, Japan).

3. Results

Figure 3 shows constant errors for the target force of the push force in two groups.

The constant error was compared with between the large contact area group and tiny contact area group. The results in all target forces was shown no significant difference ($p>0.05$), except for periods within groups.

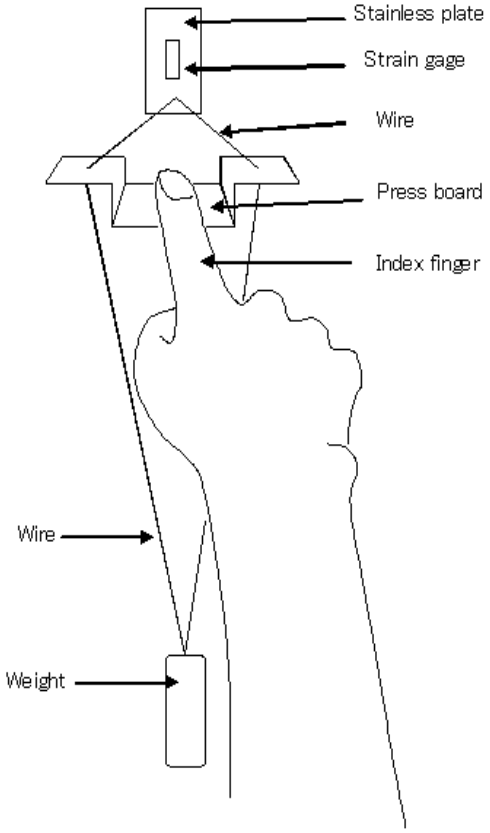

Figure 2. Detail of the device around the press board. Each subject was instructed to push on the press board at the index finger.

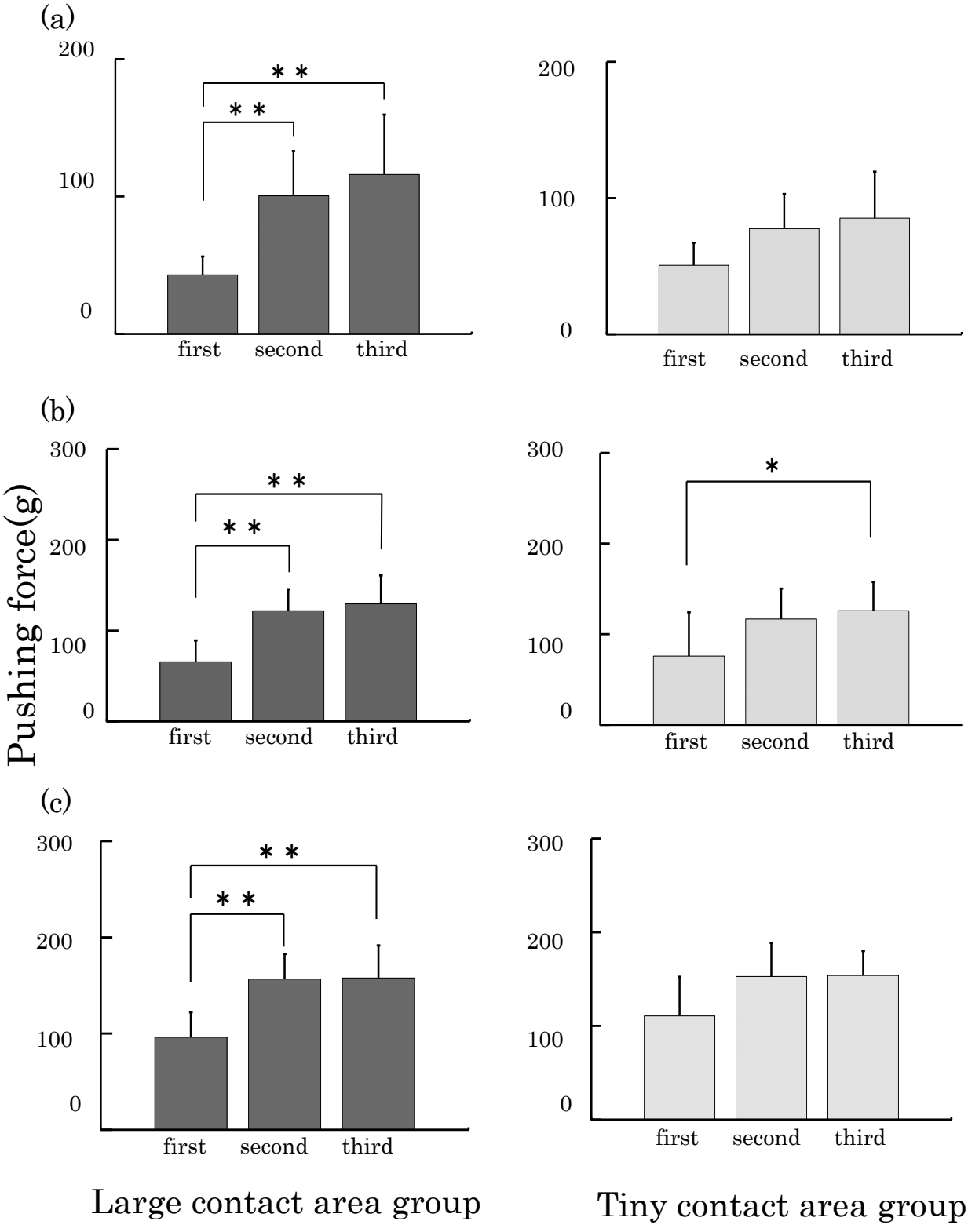

Figure 3. Constant errors between the large and tiny contact area group in pushing force at 100 g (a), at 200 g (b), and at 300 g (c). First, second, third indicate periods of the experiment. Values are indicated by mean±SD.

4. Discussion

We compared the force accuracy of the push force for different sizes of the contact area and investigated the influence of the size of the contact area.

There were no significant differences in any of the target forces between the groups ($p > 0.01$), except for periods within groups. Henningsen et al.[13] observed that as the finger force increased, information from the muscle spindles was used more efficiently than tactile afferent information. In this experiment, when learning the target force, only the tactile sense was used for the stimulus of the target force; there was little other sensory input. Therefore, we considered that the reason why there were no significant differences between the large contact area group and tiny contact area group is that the input from the tactile sense was not reflected as an output control.

5. Conclusion

The size of the contact area when using only the tactile sense does not affect the accuracy of the push force.

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