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Effects of Repeat Training of the Controlled Force Exertion Test on Dominant and Non-dominant Hands

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Abstract This study aimed to examine the effects of repeated force exertion training on a performance in the controlled force exertion (CFE) test, and the differences in effect the training has on the CFE test performances between the dominant and non-dominant hands. The subjects were the training and non-training groups. They performed the CFE test where their handgrip strengths were matched to demand values which constantly changed. The training group performed the CFE test as the repeat training over a 3 week periods. The estimates of CFE in the training group were significantly improved. The improvement of the estimates of both hands on and after 2 weeks was small, and a significant difference was not found between both hands after 3 weeks. In conclusion, the estimates of CFE in the dominant and non-dominant hands were improved by the repeat training. A difference between both hands after 3 weeks was not found.

Keywords: *laterality, repeated training, coordination, motor task, handgrip strength*

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1. Introduction

A functional right and left difference called “laterality” is found in each body part with bilateral symmetry in humans [1-4]. Laterality is the phenomenon in which one side of each organ in the body that possesses bilateral symmetry is superior on one side in the achievement of motor or cognitive tasks. The dominant hand is generally superior in muscle strength, quickness, accuracy and dexterity. The laterality appears from infancy due to the influence of inherited factors [5]. It is found particularly in movements involving the arm or fingers, such as throwing a ball, using a spoon, or writing. It results from the preferential and more frequent use of either hand in activities of daily life.

Laterality is found in the Beans with Tweezers and the pegboard tests which are two of the coordination tests used to evaluate finger dexterity. From these tests, it is found that the dominant hand is superior [6]. Ohtsuki et al. [7] clarified that the laterality of grading ability becomes more remarkable due to the influence of an acquired factor.

The controlled force exertion (CFE) test is another test used to evaluate the upper limb’s coordination. The CFE test demands that the subjects match their submaximal grip strength values to the changing demand values on a personal computer display [8,9,10]. Kubota and Demura [11] examined the laterality of the CFE in young males and females using this CFE test, and reported that the laterality in both males and females was found. Kubota et al. [12] also examined laterality in both young and elderly females, and reported that laterality in both groups was found.

Lateral dominance generally appears in motor tasks which require dexterity in the hands, fingers and upper limbs, and the dominant hand is superior [13]. Functions which involve motor tasks develop because of the frequent use of the dominant hand, and the functional development differences between both hands become increasing distinct [5,14]. Taylor and Heilman [15] examined the differences between the right and left hands in the proficiency of motor task using a complex key-pressing task, and reported that the proficiency for learning over a short period of time is greater in the left cerebral hemisphere which dominants the right (dominant) hand than in the right one which does the left (non-dominant) hand due to the result that the proficiency period in motor task is shorter in the right hand than in the left hand. Shimizu et al. [16] suggested that the motor program formation speed is faster in the cerebral hemisphere which controls the dominant hand than that in the non-dominant hand when the same motor task is performed. It is inferred that the dominant hand which is preferentially used in daily life develops a series of functions involving movements better than the non-dominant hand, and the dominant hand is also superior in the functions of peripheral and central nerve systems, thus the movements improve smoothly while the appropriate feedback is repeated.

However, the effect of the repeat training of controlled force exertion on the CFE test has not been examined sufficiently until now. From the above, it is hypothesized that the estimates of the CFE test are improved by repeat training of controlled force exertion, and differences between the dominant and non-dominant hands with respect to the effect which repeat training has on CFE test performance are found.

This study aimed to examine the effect of the repeat training of controlled force exertion on estimates of the CFE test, and the differences of the effect which the above training affects the CFE test estimates of the dominant and non-dominant hands.

2. Methods

2.1. Subjects

The subjects were 19 healthy young males which consisted of the training group: 10 males (mean age 21.8 ± 1.4 year, height 171.8 ± 5.8 cm, weight 65.2 ± 4.7 kg), and the non-training (control) group: 9 males (mean age 21.7 ± 2.7 year, height 173.3 ± 3.9 cm, weight 68.8 ± 3.8 kg). Mean values of their height and body mass were similar to Japanese normative values (Laboratory Physical Education in Tokyo Metropolitan University, 1989) (Table 1). Before the experiment was performed, all subjects were judged to be right-handed by a Demura et al. [17] handedness inquiry. No subject had sustained damage to their upper limbs. Each subject could observe the computer display without difficulty; hence, it was judged that each individual's vision did not affect our measurements. Prior to measurement, the purposes and procedures of this study were explained in detail to each subject, and the consent of participation in this study was obtained from all subjects. The protocol of this study was obtained approval by the Ethics Committee on Human Experimentation of the Faculty of Human Science, Kanazawa University (Ref. No. 2012-02).

Table 1. The means and standard deviations of age, height, weight

	Training group (n = 10)		Control group (n = 9)		t-test		
	M	SD	M	SD	t-value	p	ES
Age (years)	21.6	1.4	21.7	2.7	0.06	0.95	0.03
Height (cm)	171.8	5.8	173.3	3.9	0.63	0.54	0.29
Weight (kg)	65.2	4.7	68.8	3.8	1.70	0.11	0.78

*: $p < 0.05$, M: mean, SD: standard deviation, ES: effect size

2.2. Measurement

2.2.1. Controlled Force Exertion Test

We measured the CFE and maximal handgrip strength with a Smedley's handgrip mechanical dynamometer with an accuracy of ±0.2% in the range of 0 - 99.9 kg and a hand biofeedback system (EG-100; Sakai, Tokyo, Japan). The information from the handgrip device was transmitted at a sampling rate of 20 Hz to a computer through a data output cable after A/D conversion.

The subjects exerted grip strength using a handgrip device while sitting on a chair in front of the computer display, with the elbow straight and close to the body, without contact between the dynamometer and the body or the chair. The size of the grip was set so that they felt comfortable squeezing it. They performed the CFE test while attempting to minimize the differences between the demand and grip values that were being presented on a computer. Relative values which based on the maximal handgrip strength, but not absolute values, were used as the demand values because the grip strength of each individual is different. The demand values changed at a constant frequency. Firstly, the maximal handgrip strength was measured to set the demand values. The maximal grip strength was measured twice with a 1-min interval, and the greater value was used as the maximal grip strength value in this study. A bar chart was used to represent the data according to the criteria established by Nagasawa [9]. The demand values changed up and down at a constant frequency of 0.2 Hz from 5 to 25 % of the maximal grip strength. The program was designed to present the demand values within a constant range on the display regardless of differences in each participant's maximal handgrip strength. The duration of each trial of the CFE test was 40 seconds, and the CFE was estimated using the data, excluding the first 15 seconds of each trial, considering a stable time of performance. The sum of the differences between the demand value and the grip exertion value was used as the estimates of the CFE. A smaller difference was interpreted to mean the superior CFE. The subjects performed the CFE test 3 times after one practice trial, and the mean of the second and third trials was used as a representative value.

2.2.2. Experimental Procedure and Repeat Training

The training group performed repeat training of controlled force exertion (4 trials per day by the dominant and non-dominant hands). The training was conducted the same procedure as the CFE test, and the estimates of the CFE were recorded every time. The repeat training was performed 5 days per week over a period of 3 weeks, for a total of 15 times. The control group was performed the CFE test at only initial time and after 3 weeks. Here, it is important to note that both groups were not restricted to daily life.

2.3. Statistical Analysis

The data were reported using ordinary statistical methods, including mean (M) and standard deviation (± standard deviations, SD). A two-way analysis of variance (group and time) was used to examine significant differences among the means of the estimates of the CFE and the maximal handgrip strength by the dominant and non-dominant hands. A two-way analysis of the variance (dominant/non-dominant hands and training time) was used to examine significant differences between means of the estimates of the CFE. When significant interaction or a main effect was found, a multiple-comparison test was performed using Tukey's Honestly Significant Difference (HSD) method. The level of significance was set a priori to 0.05.

3. Results

Table 2 shows the means and standard deviations of maximal handgrip strength of the dominant hand according to the first time and after 3 weeks in the training and control groups, and the test results of the two-way ANOVA. An insignificant interaction or main effect was found.

Table 2. Means of maximal handgrip strength in the dominant hand by each group and test result (two-way ANOVA)

	Training (n = 10)		Control (n = 9)			F-value	Partial η^2
	M	SD	M	SD	F1	0.01	0.00
First time	50.1	5.6	51.4	4.5	F2	0.59	0.03
After 3 weeks	52.0	8.8	51.1	2.4	F3	0.95	0.05

unit :%, *: $p < 0.05$, F1: training, F2: time, F3: intaeraction, M: mean, SD: standard deviation

Table 3 shows the means and standard deviations of maximal handgrip strength of the non-dominant hand according to the first time and after 3 weeks in the training and control groups, and the test results of the two-way ANOVA. An insignificant interaction or main effect was found.

Table 3. Means of maximal handgrip strength in the non-dominant hand by each group and test result (two-way ANOVA)

	Training (n = 10)		Control (n = 9)			F-value	Partial η^2
	M	SD	M	SD	F1	0.00	0.00
First time	46.1	3.7	47.8	5.8	F2	1.16	0.06
After 3 weeks	48.9	6.1	47.2	1.9	F3	2.34	0.12

unit :%, *: $p < 0.05$, F1: training, F2: time, F3: intaeraction, M: mean, SD: standard deviation

Table 4 shows the means and standard deviations of the CFE estimates of the dominant hand according to the first time and after 3 weeks in the training and control groups, and the test results of the two-way ANOVA. A significant interaction was found. Multiple comparisons showed that, in the training group, the estimate of the CFE after 3 weeks was smaller than the first value obtained the first time the test was performed. After 3 weeks, the estimate of the CFE in the training group was smaller than that in the control group.

Table 4. Means of eatimate of the CFF in the dominant hand by each group and test result (two-way ANOVA)

	Training (n = 10)		Control (n = 9)			F-value	Partial η^2	Post-hoc
	M	SD	M	SD	F1	4.65*	0.21	
First time	569.1	150.1	568.6	157.7	F2	44.68*	0.71	Training group: first time > after 3 weeks after 3 weeks: training group < control group
After 3 weeks	269.6	67.7	524.2	128.8	F3	21.43*	0.54	

unit :%, *: $p < 0.05$, F1: training, F2: time, F3: intaeraction, M: mean, SD: standard deviation

Table 5 shows the means and standard deviations of the CFE estimates of the non-dominant hand according to the first time and after 3 weeks in the training and control groups, and the test results of the two-way ANOVA. A significant interaction was found. Multiple comparisons showed that, in the training group, the estimate of the CFE after 3 weeks was smaller than the value taken during the initial measurement. After 3 weeks, the estimate of the CFE in the training group was smaller than that in the control group.

Table 5. Means of eatimate of the CFF in the non-dominant hand by each group and test result (two-way ANOVA)

	Training (n = 10)		Control (n = 9)			F-value	Partial η^2	Post-hoc
	M	SD	M	SD	F1	7.68*	0.30	
First time	632.3	126.7	622.1	106.6	F2	76.21*	0.81	Training group: first time > after 3 weeks after 3 weeks: training group < control group
After 3 weeks	327.0	76.8	584.0	123.3	F3	42.48*	0.70	

unit :%, * :$p < 0.05$, F1: training, F2: time, F3: intaeraction, M: mean, SD: standard deviation

Table 6 shows the means and standard deviations of the estimates of the CFE according to the dominant and non-dominant hands in the training group, and the test results of two-way ANOVA. A significant effect was found in both main factors. Multiple comparisons showed that, the estimates of the CFE on and after 4-6 times were smaller than that on 1-3 times for both hands, and the estimates of the CFE on and after 7-9 times were smaller than that on 4-6 times for both hands. A significant difference between the dominant and non-dominant hands was found on 1-3, 4-6, 7-9, and 10-12 times, but not on 13-15 times.

Table 6. Means of eatimate of the CFF in the dominant and non-dominant hands by training group and test result (two-way ANOVA)

	Dominant		Non-dominant					
time	M	SD	M	SD		F-value	Partial η^2	Post-hoc Tukey's HSD
1-3	480.4	99.3	543.1	93.1	F1	94.31*	0.91	1-3, 4-6, 7-9, 10-12: Dom < Non-dom
4-6	385.7	76.6	429.6	69.7	F2	90.33*	0.91	Dom , Non-dom: 1-3 > 4-6 > 7-9, 10-12, 13-15
7-9	330.3	60.7	379.8	70.0	F3	1.91	0.17	
10-12	324.2	69.9	372.1	92.9				
13-15	314.0	58.7	336.1	69.2				

unit :%, *: $p < 0.05$, F1: training, F2: time, F3: intaeraction, M: mean, SD: standard deviation

4. Discussion

From the present results, it was found that although the estimates of the CFE of the dominant and non-dominant hands are improved by repeat training of controlled force exertion, their improvement was large in the early stage (on one week) and tapered off after 2 weeks.

In general, the tests that strongly involve nerve function are significantly affected influenced by repeated trials (practice) at an early stage [18]. Butki [19] examined the effects of 15 trials on tracking action tests by using 60 subjects, and reported that subjects needed 4 trials to understand test content and show significant improvement, and that measurements were almost stable after the 9th trial. Noguchi et al. [20] reported that the subjects efficiently conducted the motor task due to becoming accustomed to the task over multiple trials which helped them to better understand the procedure. All subjects in this study performed the CFE test for the first time. Therefore, it is inferred that although they were unfamiliar with the test at the early stage, the records improved with each measurement because they became more familiar with the test tasks through repeated practice.

In addition, Nakamura et al. [21] reported that the learning effect of the tracking task was related with both factors of comprehending the target trajectory (declarative memory) and improvement of procedure tracking of a target (procedural memory). It is suggested that both memories improved the estimate of the CFE by promoting leaning, because the conditions of the CFE test used in this study were the same relative load and the same speed in each trial and training. In the CFE test, the visual and perceptual information from peripheral tissues is processed in the brain, and muscle strength is exerted by motor commands from the brain. In short, the subjects consider a size of error between demanded and exerted values based on visual feedback, and coordinate force output by motor commands [12]. It is inferred that the cognitive information processing, the motor command, and the force output toward them became accurate by the repeat training.

From the present results, it was clarified that the difference between the dominant and non-dominant hands in the CFE test, which was found at the beginning of training, was lost after 3 weeks of repeat training. Taylor and Heilman [15] examined the differences between the right and left hands in the proficiency of motor task by using the complex key-pressing task, and reported that the dominant hand has a shorter proficiency period in motor task and higher proficiency in learning than the non-dominant hand. Shimizu et al. [16] suggested that the motor program formation speed in the dominant hand is faster than that in the non-dominant hand when performing the same motor task. Noguchi et al. [20] examined the improvement rate by repeat trials in the dominant and non-dominant hands by using tracking motor task, and reported that the improvement rate is larger in the dominant hand. It is considered that the dexterity and coordination of eyes and hands in the dominant hand, which is used frequently in daily life, is more developed. From the above, we also learned in this study that the dominant hand may have been superior at the start and the early stages of the training.

One the other hand, the difference between the dominant and non-dominant hands is lost after 3 weeks. Noguchi et al. [18] reported that lateral dominance exists in the practice effect in the Beans with Tweezers test, from results that the practice effect is found only in the non-dominant hand. For reasons not found in the dominant hand, it was discussed that the dominant hand is frequently used due to the fact that it is frequently required to perform similar movements similar to those in the Beans with Tweezers test in daily life. The practice effect of the dominant hand in the motor tasks, which are similar to more movements in daily life, may be lost when the coordination is improved to a certain level. In addition, the non-dominant hand is inferior in neural mechanism related movements toward the changing target, i.e. peripheral muscle activity and exertion of nerve-muscle function, to the dominant hand and thus it takes more time to prescribe the motor range [22]. From the above, it is inferred that the difference between the dominant and non-dominant hands finally became small because performances of the non-dominant hand were improved markedly in later stage in addition to the fact that the improvement speed in the dominant hand was rapid and the performance reached an upper limit.

5. Conclusion

The estimates of the CFE in the dominant and non-dominant hands were improved by the repeat training of controlled force exertion. However, a difference between the dominant and non-dominant hands after 3 weeks was not found.

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