Advances in Physical Education, 2017, 7, 473-479
http://www.scirp.org/journal/ape
ISSN Online: 2164-0408
ISSN Print: 2164-0386

Laterality of Accuracy of Grip and Elbow Flexion Force Exertions and Their Differences

Hiroki Aoki[1]*, Shin-Ichi Demura[2]

[1]Fukui National College of Technology, Fukui, Japan
[2]Kanazawa University, Ishikawa, Japan
Email: *aoki@fukui-nct.ac.jp

How to cite this paper: Aok, H., & Demura, S.-I. (2017). Laterality of Accuracy of Grip and Elbow Flexion Force Exertions and Their Differences. *Advances in Physical Education, 7,* 473-479.
https://doi.org/10.4236/ape.2017.74039

Received: October 26, 2016
Accepted: November 25, 2017
Published: November 28, 2017

Abstract

Accuracy of grip and elbow flexion force exertions has been examined. Because agonist muscles related to the achievement of these movements differ, the laterality of their accuracy may also differ. This study aimed to examine the accuracy of grip and elbow flexion force exertions for each demand value and the difference between movements. Participants were 22 right-armed healthy young males (mean age 22.5 ± 5.6 yrs, mean height 170.9 ± 5.8 cm, mean weight 62.4 ± 9.4 kg). Demand values of 25%, 50%, and 75% of maximum voluntary contraction (MVC) were selected. Using subjective judgment, participants were requested to exert each arm's handgrip and elbow flexion forces for each demand value. Evaluation parameters were differences (errors) between demand and exertion values and their total error. Results of two-way ANOVA (laterality and demand value) showed a significant interaction in grip movement. In results of multiple comparisons, an error in 25% MVC was greater than that in 50% MVC and 75% MVC in the non-dominant arm. For elbow flexion movement, a significant difference was found in a demand value factor, and results of multiple comparisons showed that error was greater in the order of 25% MVC, 50% MVC, and 75% MVC in the non-dominant arm; in the dominant arm, error was greater in 25% MVC than in 50% MVC and 75% MVC. Total error showed significant interaction and was greater in elbow flexion strength than in grip strength in the non-dominant arm. In conclusion, the non-dominant arm had less error with greater demand values in grip and elbow flexion strengths, and laterality was not found in either movement at each demand value. Accuracy of force exertion in elbow flexion strength was inferior to grip strength.

Keywords

Hand Grip Strength, Elbow Flexion Strengths, Laterality

1. Introduction

Humans generally exert submaximal strength based on a subjective sense of the force needed in daily life and in sports situations. Until now, coordination of force exertion has been evaluated by tests as follows: Exert a handgrip coordinately while adjusting an index shown on a screen (Kubota et al., 2012); exert handgrip, elbow flexion, and pinch strengths based on subjective judgment while accurately matching each relative demand value of maximum voluntary contraction (MVC) (Seki & Ohtsuki, 1995; Kitabayashi et al., 2013). Demura et al. (2001) demanded participants to exert 25%, 50%, and 75% of maximum isokinetic knee extension strength; they reported finding no differences between each demand value and actual output value. Noguchi et al. (2014) reported that the accuracy of handgrip exertions showed insignificant differences among demand values of 20% MVC, 40% MVC, 60% MVC, and 80% MVC.

Furthermore, humans demonstrate functional right and left differences in each bilaterally symmetrical body part; this is called "laterality" (Dolcos et al., 2002; Bohannon, 2003; Roy et al., 2003; Noguchi et al., 2009). Laterality is particularly noticeable in functions of fingers, such as in using a spoon or writing letters, and is considered to occur from more preferential and frequent use of one hand in daily activities. Until now, lateral dominance of muscle function has frequently been reported. Seki and Ohtsuki (1995) reported that accuracy of exertion values (errors between each demand and exertion value) in elbow flexion showed little difference between dominant and non-dominant arms. However, Kitabayashi et al. (2013) reported that error between demand (50% MVC) and exertion values in pinch strength was less in the dominant than in the non-dominant hand. In this way, laterality in accuracy of force exertion differs even in the same upper limbs. This is why agonist muscles contributing to the achievement of each movement seem to differ. Agonist muscle is a muscle group in the fingers and antebrachium for handgrip and in biceps brachii for elbow flexion. Hence, laterality in accuracy of force exertion may differ between handgrip and elbow flexion in spite of movement in the same upper limb.

Thus, for demand values in grip and elbow flexion, this study examined laterality in accuracy of exertion force.

2. Method

2.1. Participants

Participants were 22 healthy young males (mean age 22.6 ± 4.3 yrs, mean height 172.7 ± 7.0 cm, mean weight 75.0 ± 12.3 kg). Based on Demura et al.'s (2009) dominant arm survey, they were all judged to be right-handed. We explained to them the purpose, methods, and risks of the experiment and obtained their consent. This study's protocol was approved by the Ethics Committee on Human Experimentation of the Faculty of Human Science, Kanazawa University (approval number: 2012-02).

2.2. Experimental Instruments and Methods

Grip strength and elbow flexion strength were measured using the dynamometry device (YG-100, Yagami, Japan). Demand values selected in force exertion tests were 25%, 50%, and 75% of the maximum handgrip and elbow flexion strength (Seki & Ohtsuki, 1995). For measurement of handgrip strength, participants sat on an adjustable ergometric chair, and the arm, supported by an armrest, was in a sagittal and horizontal position, with the forearm vertical to the hand, in a semi-prone position. For each individual, grip width could be adjusted with a dial to achieve a 90-degree angle with the proximal-middle phalanges.

For measurement of elbow strength, participants sat on an adjustable ergometric chair sideways and placed their axilla on the table's edge, with supination of the forearm. After participants touched their palms to the handle, isometric strength exertion by elbow flexion (joint angle of 90 degrees) was measured.

Participants performed the maximum voluntary contraction (MVC) test twice with both arms, and the higher value was used as the MVC. Participants were divided at random into two groups who began measurements from the right or left arm. Two trials with a 2-min rest were performed for each demand value. We did not provide participants with their measurement values.

After that, participants selected the order of demand values at random for each arm from the following six patterns: 1) 25% → 50% → 75% MVC; 2) 25% → 75% → 50% MVC; 3) 50% → 25% → 75% MVC; 4) 50% → 75% → 25% MVC; 5) 75% → 25% → 50% MVC; and 6) 75% → 50% → 25% MVC. Differences (errors) between demand and exerted values for each trial (25%, 50% and 75% MVC) were calculated. The less error of two trials was used as a parameter. In addition, a total error of demand value was calculated in dominant and non-dominant arms.

2.3. Statistical Analysis

Intra-class correlation coefficient (ICC) for each test was calculated to examine reliability. Two-way ANOVA (demand value x dominant/non-dominant arm) was used to examine differences among mean errors. Two-way ANOVA (move difference x dominant/non-dominant arm) was used to examine mean differences between total error of the dominant and non-dominant arms. When a significant interaction or main effect was found, a Tukey's Honestly Significant Difference (HSD) test was used for multiple comparisons. The level of significance was determined to be 0.05.

3. Results

ICCs of three trial errors were 0.63 - 0.85 in the dominant arm and 0.55 - 0.85 in the non-dominant arm.

Table 1 shows basic statistics for errors in handgrip strength according to demand values, dominant and non-dominant arms, and results of two-way ANOVA. Significant interaction was found. Multiple comparison tests showed that error was greater in 25% MVC than in 50% MVC and 75% MVC in the non-dominant arm.

Table 2 shows basic statistics for elbow flexion strength errors according to demand values, dominant and non-dominant arms, and results of two-way ANOVA. Significant main effect was found. Multiple comparison tests showed that error was greater in the order of 25% MVC, 50% MVC, and 75% MVC in the dominant arm; in the non-dominant arm, error was greater in 25% MVC than in 50% MVC and 75% MVC.

Table 3 shows basic statistics for total error according to hand and elbow

Table 1. Basic statistics for handgrip strength errors according to demand values, dominant and non-dominant arms, and results of two-way ANOVA.

	25% MVC		50% MVC		75% MVC		F-Value (degree of freedom)	Post-hoc
	Mean	SD	Mean	SD	Mean	SD	F1: 0.26 (1, 21)	Non dominant: 25% MVC > 50% MVC, 75% MVC
Dominant (%)	13.2	13.5	10.2	8.9	10.1	8.6	F2: 3.06 (2, 42)	
Non dominant (%)	15.3	12.4	9.5	8.1	6.4	7.1	F3: 4.66* (2, 42)	

*$p < 0.05$; F1: demand value; F2: dominant/non-dominant arms; F3: interaction.

Table 2. Basic statistics for elbow flexion strength errors according to demand values, dominant and non-dominant arms, and results of two-way ANOVA.

	25% MVC		50% MVC		75% MVC		F-Value (degree of freedom)	Post-hoc
	Mean	SD	Mean	SD	Mean	SD	F1: 5.96* (1, 21)	Dominant: 25% MVC > 50% MVC, 75% MVC
Dominant (%)	16.8	13.9	6.9	7.1	5.4	5.9	F2: 12.36* (2, 42)	Non dominant: 25% MVC > 50% MVC > 75% MVC
Non dominant (%)	19.5	17.3	11	7.2	7.3	12.2	F3: 6.65* (2, 42)	

*$p < 0.05$; F1: demand value; F2: dominant/non-dominant arms; F3: interaction.

Table 3. Basic statistics for total error according to hand and elbow flexion movement, dominant and non-dominant arms in handgrip and elbow flexion strength, and results of two-way ANOVA.

	Hand grip		Elbow flexion		F-Value (degree of freedom)	Post-hoc
	Mean	SD	Mean	SD	F1: 1.17 (1, 21)	Non dominant: Elbow flexion > hand grip
Dominant (%)	33.5	20.8	32.1	19.7	F2: 1.50 (1, 21)	
Non dominant (%)	31.3	20.8	41.7	25.6	F3: 5.32* (1, 21)	

*$p < 0.05$; F1: demand value; F2: dominant/non-dominant arms; F3: interaction.

flexion movement, dominant and non-dominant arms in handgrip and elbow flexion strength, and results of two-way ANOVA. Significant interaction was found. Multiple comparison tests showed that total error was greater in elbow flexion strength than in handgrip strength for the non-dominant arm.

4. Discussion

The present results showed that errors between demand and exertion values in subjective force exertion of handgrip strength are greater in 25% MVC than in 50% MVC and 75% MVC in the non-dominant arm and that accuracy of force exertion differs among demand values. Noguchi et al. (2014) reported finding no significant difference among demand values of 20% MVC, 40% MVC, 60% MVC, and 80% MVC in accuracy of handgrip exertion, regardless of difference of demand values in the dominant arm. Handgrip is movement using plural small joints, and the innervation ratio of hand and finger muscle groups related to the movement is high (Nagata et al., 1976). In other words, exerting force to adjust demand values in the dominant hand's muscle groups is easy because they are frequently used in daily life. Additionally, accuracy of force exertion among demand values might not show any difference in dominant handgrip movement.

In the present results, errors between demand and exertion values of elbow flexion strength differed among 25% MVC and demand values of 50% MVC and 75% MVC in both arms. According to Demura et al.'s (2001) report, which examined differences between demand and exertion values in isokinetic knee extension strength using dominant and non-dominant legs, insignificant difference was found between demand values of 25%, 50%, and 75% of maximum strength. In contrast, Seki and Ohtsuki (1995) reported that error between strength exertion value based on subjective judgment and demand value decreases with increased demand. In a case of small demand value, such as 25% MVC, compared with great demand value approaching maximum strength, such as 75% MVC, errors between demand and exertion values are great probably because participants find it difficult to imagine sizes of exertion force. Thus, it is also possible that accuracy of force exertion among demand values differed between 25% MVC and greater demand values of 50% MVC and 75% MVC in elbow flexion movement.

In the non-dominant arm, total error was greater in elbow flexion strength than in handgrip strength. Ohtsuki (1996) reported that development of controlled force-exertion ability is affected by acquired learning experience. Sadamoto and Ohtsuki (1977) reported that accuracy of programming formed by past movement learning and experience, and the output mechanism converting the program to output force, are included in coordination of force output. Although handgrip is movement using plural small joints and the innervation ratio of hand and finger muscle groups related to the movement is high, elbow flexion uses a single large joint, and the innervation ratio of the biceps brachii as its agonist muscle is low (Nagata et al., 1976). Hence, the former muscle groups can easily be adjusted to exert strength appropriate to demand values, but using biceps brachii for elbow flexion to perform minute force exertion is difficult. Possibly, because the non-dominant arm's elbow flexion movement is used little in daily life, the tendency becomes marked, so total error was greater in elbow flexion movement than in handgrip movement in the non-dominant arm.

Errors of each demand value and total error did not show differences between dominant and non-dominant arms. In short, laterality was not found in the accuracy of handgrip and elbow flexion movements' force exertions. Kubota et al. (2012) reported that ability to exert handgrip coordinately is superior in the dominant hand, and thus laterality was found. In addition, according to Noguchi et al.'s (2009) report, due to it being used more frequently, functions related to achievement of operation in the dominant hand develop, and the difference between hands becomes remarkable. However, accuracy of force exertion differs from the ability to exert a handgrip coordinately while adjusting an index shown on a screen. Ia group nerve fibers of muscle spindle contribute to control strength exertion (Yoshitake et al., 2011). Because this difference between the dominant and non-dominant arms is small, laterality might not occur in either handgrip or elbow flexion movements.

5. Conclusion

With greater demand values, the non-dominant arm demonstrated less error in handgrip and elbow flexion strength, and each demand value did not show lateral dominance. In elbow flexion strength, the accuracy of force exertion is inferior to handgrip strength.

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