Title: Laterality of hand grip and elbow flexion power in right hand dominant individuals

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Abstract

**Purpose:** This study aimed to compare the laterality, and its gender difference, of hand grip and elbow flexion power according to load in right hand dominant individuals. **Methods:** The subjects were 15 healthy young males (age 22.1±0.7yr, height 171.3±3.4cm, mass 64.5±4.1kg) and 15 healthy young females (age 22.4±1.0yr, height 161.1±3.0cm, mass 55.4±4.6kg). Isotonic peak power was measured with 6 different loads ranging from 20-70% of maximum voluntary contraction (MVC) for grip and elbow flexion movements. **Results:** The peak power was significantly larger in males than in females in both movements (males: females: 58.1:49.4%). The dominant right hand had larger peak power in all loads for hand grip power (dominant: non-dominant: 83.6: 71.1%) and in loads of 20-50%MVC for elbow flexion power (88.7: 85.7%) in both genders, confirming laterality in both movements. The peak power ratio of the dominant right hand to the non dominant left hand was significantly larger in hand grip than in elbow flexion for all loads in females. **Conclusion:** While laterality was confirmed in both grip and elbow flexion, gender difference is more marked in hand grip.

**Keywords:** lateral dominance, gender, muscle power
Introduction

Muscle power is the ability to exert large amounts of energy within a very short time, and it is an important physical fitness element for athletes and young adults. Until now, the power of the entire body or relatively large muscle groups has been typically measured. However, in daily life, whole body exertion is rarely required even in young adults. Rather, local muscle power, such as hand grip or elbow flexion, is generally used. In middle aged and elderly people, whole body exertion is not optimal from the viewpoint of physical burden and safety. Thus, the muscle power of the upper limbs is more frequently studied regardless of gender and age level due to its safety and greater applicability.

Elbow flexion power and hand grip power are representative of upper limb strength in athletes and young adults. Elbow flexion power has been the focus of previous studies. However, hand grip may be used more often in daily life, in activities such as catching and gripping an object, opening canned food, applying the brake of a bicycle, etc.

Muscle power is determined by force and contraction velocity. The size of loads used in a power test greatly affects both factors. Power depends strongly on muscle contraction velocity for light loads and on maximal muscle strength for heavy loads. Ikemoto et al. reported that when gripping throughout a small range of motion, the contribution of muscle contraction velocity to peak power is larger than that of maximal strength. However, elbow flexion has a larger range of motion than hand grip and a larger contribution of maximal strength to peak power. Thus, the power characteristics of hand grip and elbow flexion may differ greatly.

On the other hand, human limbs have a unique functional superiority in daily life and competitive sports, i.e. writing characters, using scissors, and throwing or hitting a ball. Hence, the laterality of upper limb muscle power has been examined. Miyaguchi & Demura suggested that elbow flexion power is superior in the dominant hand for males, but stretch-shortening cycle (SSC) performances are superior in the non-dominant hand. Aoki & Demura reported that the muscle power of the dominant hand is larger in all loads (20-70% maximum voluntary contraction (MVC)) for hand grip and in loads of 20% and 30%MVC for elbow flexion. From the above, the muscle power of the upper limbs is judged to be superior in the dominant hand. However, the laterality of hand grip and elbow flexion powers and its gender difference have not been examined in detail.

The muscle power exerted in daily life and competitive sports varies according to load. Aoki & Demura reported that only elbow flexion power showed an effect of load on laterality and that this effect was more marked in heavy loads than in light loads. Kaneko reported that unlike maximal muscle strength, muscle contraction velocity does not show a large gender difference. Ikemoto et al. reported that the gender difference of grip muscle power increases with load (20-50%MVC). It is assumed that the effect of load on the laterality of hand grip and elbow flexion differs between males and females.

This study aimed to examine the laterality of hand grip and elbow flexion power and its gender difference according to load.

Methods

Subjects

The subjects were 15 healthy young males (age 22.1±0.7 yr, height 171.3±3.4cm, mass 64.5±4.1kg) and 15 healthy young females (age 22.4±1.0 yr, height 161.1±3.0cm, mass 55.4±4.6kg) without upper arm disorders. The experimental purpose, methods and risks were explained to each subject before obtaining their consent. Prior to beginning the experiment, all subjects were confirmed to be right-handed using the Oldfield's 14
handedness inquiry. The present protocol was approved by the Kanazawa University Department of Education Ethical Review Board.

Experimental device

The velocity of the load as measured by the dynamometry device (YH100, YAGAMI, Japan) was used to calculate muscle power. This device measures velocity using a fixed pulley with a rotary encoder and a recording device. The load is connected by a wire through the fixed pulley. The velocity curve can be created using time series data. We assumed the peak of this curve to be the peak velocity. The fixed pulley rotates when the handle is pulled, and the rotary encoder measures the rotation angle with an optical resolution of 1200 pulses/turn. A fixed pulley sends pulses every rotation of 0.3 degrees with the movement of a wire. The pulses were converted A/D into a moving distance of the load per unit time with a sampling frequency of 100Hz by a recording device. The moving distance of the load was 5-7 cm with hand grip and 15-17 cm with elbow flexion, and the recording device calculated the moving velocity of the load from the distance and per unit time. We calculated the peak power from the product of the load and the greatest moving velocity based on previous studies\textsuperscript{15,16} and defined it as respective hand grip power and elbow flexion power.

By inserting the peak moving velocity of the load (peak velocity) into the following equation, the peak powers of each subject for each load of 20-70\%MVC were calculated.

\[
\text{Peak power (W)} = \text{peak velocity (m/sec)} \times 9.8 \text{ (m/sec}^2\text{)} \times \text{load (kg)}
\]

Experimental procedure

During measurement of hand grip power, subjects attached their palm to the fixed bar, and grasped the handle with four fingers, and then explosively pulled the handle to the fixed bar. Subjects 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. The grip width could be arbitrarily adjusted for each individual by a dial to achieve a 90 degree angle with the proximal-middle phalanges. During measurement of elbow flexion power, subjects sat in an adjustable ergometric chair sideways and put their axilla on the edge of the table with supination of the forearm. A bowling protector was worn to restrict the movement of the wrist. The subjects touched their palm to the handle and explosively pulled the handle with a rope that was connected to a constant load mass by elbow flexion.

The subjects performed the MVC test twice before the power test to determine the relative loads and the higher value was used as the MVC. The load was selected as 20, 30, 40, 50, 60 and 70\% of MVC and the moving velocity of the load in both hands was measured as described previously.\textsuperscript{6} Each load was set by 100g unit and the value was rounded to the nearest hundredths. The subjects performed the same test again two to three days later. Each subject performed each test twice on the same day. They were instructed to exert maximal force as fast and as forcefully as possible immediately after hearing a beeping sound from the device.

In addition, according to the report by Ikemoto et al.\textsuperscript{6}, the peak power showed high correlations (more than 0.7) with the time of the greatest moving velocity and the mean transit time from the beginning to the end of the movement. Furthermore, there was little variance in the power curve near the peak. Thus, the peak power was judged to be a valid representative parameter of the power curve.

Statistical analysis

The intra-class correlation coefficient (ICC) for each test was calculated to evaluate trial-to-trial reliability. The significance of the above coefficients was tested. Three
way ANOVA (gender, dominant/non dominant hands and loads) was used to reveal mean differences of peak power. Three way ANOVA (gender, movement and loads) was used to reveal the mean differences of the ratio of the dominant to non dominant hands. Tukey’s Honestly Significant Difference (HSD) test was used for multiple comparisons. To evaluate mean differences, effect size (ES) based on Cohen’s $d^{18,19}$ was calculated. The ES was interpreted based on conventional operational definitions ("small, $d=0.2$," "medium, $d=0.5$," and "large, $d=0.8$") by Cohen.$^{18}$ All analyses were performed with SPSS for Windows®.

Results

The ICC’s of maximal strength and peak power were very high, averaging $0.80(0.88 \sim 0.96)$. Hence, the mean value of two trials was used for further analysis.

Table 1 shows the mean maximal hand grip strength according to dominant and non dominant hands and gender as well as the results of two way ANOVA analysis. Gender and laterality were found to have a significant effect, and males had greater grip strengths than females in both hands. The dominant hand was greater in both genders.

Table 2 shows the mean maximal elbow flexion strength according to dominant and non dominant hands and gender as well as the results of two way ANOVA analysis. Gender and laterality were found to have a significant effect, and males had greater grip strengths than females in both hands. The dominant hand was greater in both genders.

Figure 2 reveals the mean peak power achieved at each relative load for males and females and dominant or non dominant side in a hand grip movement. Three-way ANOVA showed a significant effect in gender (F-value=201.73, $p<0.05$), laterality (F-value=163.35, $p<0.05$), and load (F-value=108.05, $p<0.05$) factors. Multiple comparisons showed that males had greater power in both hands and in all loads, while the dominant right hand was greater in both genders and in all loads. Forty and 50%MVC were larger than 20 and 70%MVC in both genders and in both hands.

Figure 3 shows the mean peak power achieved at each relative load for males and females and dominant or non dominant side in an elbow flexion movement. The three-way ANOVA showed a significant effect in gender (F-value=287.94,$p<0.05$), laterality (F-value=124.19, $p<0.05$), and load (F-value=45.38, $p<0.05$) factors. Multiple comparisons showed that males had greater power in both hands and in all loads, while the dominant right hand was greater in both genders and at 20-50%MVC. The 40 and 50%MVC were larger than the 20 and 70%MVC in both genders and in both hands.

Figure 4 shows the ratios of peak power of the dominant hand to the non dominant hand according to gender, laterality, and load factors. A significant effect was found in gender (F-value=20.87, $p<0.05$), movement (F-value=38.58, $p<0.05$), and load (F-value=10.17, $p<0.05$) factors. Multiple comparisons showed that females had a larger ratio than males in all loads in hand grip movement, hand grip had a higher ratio than elbow flexion in all loads in females for movement, and the ratio of 20%MVC was higher than that of 60 and 70%MVC in elbow flexion for males.

Discussion

The peak power of the dominant right hand was significantly larger in all loads for hand grip and in loads of 20-50%MVC for elbow flexion, and the ES (1.69-2.29) was large in both movements. Laterality was confirmed in both hand grip and elbow flexion in both genders. Previously, Incel et al.$^{20}$ reported that maximum grip strength was significantly larger in the dominant arm, while Józsa et al.$^{21}$ reported that the ratio of type II fibers was significantly higher in the dominant hand. Saito et al.$^{22}$ suggested that the
The antebrachium muscle group of the dominant arm has more fast twitch fibers than that of the non-dominant hand. These reports suggest that muscle strength and muscle contraction velocity related to both movements are superior in the dominant hand. From the present results, laterality of both movements was found in both genders and muscle power was superior in the dominant hand.

Laterality of peak elbow flexion was not found in heavy loads. Ohtsuki reported that symmetric movements are more used during large exertions like lifting or pushing large or heavy objects. In daily life, we use the dominant arm when lifting light objects, but use both arms when lifting and carrying heavy objects. Benecke et al. reported that a right/left difference of muscle strength in proximal muscle groups may be small. From the above, it is inferred that a right/left difference of elbow flexion may be smaller than that of hand grip. Laterality of elbow flexion power was not found in heavy loads which depend strongly on maximum muscle strength, because we use both arms when lifting heavy loads.

In all loads, the ratio of peak power of the dominant right hand to the non-dominant left hand is greater in females than in males for hand grip. According to Aoki & Demura, females have a larger difference of maximum grip strength between dominant and non-dominant hands. In addition, the moving velocity of loads was significantly greater in all loads for females and in lighter loads (20-50%MVC) for males. Ikemoto et al. reported that the gender difference of muscle power increases with load, because of a gender difference of the muscle contraction velocity. From these reports, the difference between the hand grip of dominant and non dominant hands is larger in females than in males for maximum muscle strength and muscle contraction in heavy loads. Hence, the laterality of hand grip power may be more marked in females.

The peak power ratio of the dominant right hand to the non dominant left hand during elbow flexion did not show a gender difference. Ellenbecker & Roetert reported that there was no laterality in isokinetic elbow flexion strength in either gender. In addition, Matunaga et al. reported that there is no difference in muscle fiber composition of the biceps brachii in either arm. The above suggests that there neither a difference in muscle strength and muscle contraction velocity of elbow flexion between the dominant and non-dominant hands nor a gender difference. Thus, it is inferred that a gender difference was not found in the laterality of elbow flexion power.

In addition, the peak power ratio of the dominant right hand to the non dominant left hand was significantly larger in 20%MVC than in 60 and 70%MVC in elbow flexion for males. This result suggests that the effect of load size on the laterality of elbow flexion power differs between males and females. The laterality of elbow flexion power is more marked when using very light loads (20%MVC) in males. Hence, it will be necessary to consider the load size during training to increase arm muscle power. According to Aoki & Demura, the peak velocity of the dominant hand was significantly larger in light loads of 20% and 30%MVC in elbow flexion for males. Also in this study, the laterality of elbow flexion power with light loads was confirmed in both genders. Hence, a difference between the dominant hand and non dominant hands of muscle contraction velocity may be large in light loads for elbow flexion regardless of gender. Aoki & Demura suggested that the difference of muscle contraction velocity in heavy loads between the dominant and non dominant arms is larger in females than in males. In addition, Kaneko reported that muscle contraction velocity was significantly larger in males than in females for elbow flexion, and the gender difference increases with load. In this study, the male/female ratio of peak moving velocity of the load (dominant elbow flexion movement) was 76.4%. This value was almost the same as the male/female ratio (74.5%) of peak velocity reported by Kaneko. From the above, it is inferred that a difference of muscle contraction velocity differs
more between dominant and non dominant hands in heavy loads as well as light loads in females than in males for elbow flexion, thus there is no laterality among light and heavy loads in females differing from males in elbow flexion.

Finally, the subjects of this study were all right-handed, thus we need to examine the laterality of upper limb power of left handed persons in the future. In addition, although this study examined laterality of an isolated muscle power, maximal muscle power or submaximal intermittent muscle power are used in many competitive sports. Hence, we will need to examine this problem in the future.

**Practical Application**

Exertion characteristics of muscle power influence competitive performances. For example, because tennis players and badminton players overuse the dominant hand, it may be important for them to emphatically increase muscle power of the dominant hand. On the other hand, because weightlifters, rowers, and swimmers generally exert both arms at the same time, it will be important for them to reduce differences between the two arms. The present results suggest that laterality exists in upper limb muscle power regardless of sex. Hence, when training to increase arm muscle power, sports competitors should consider their sporting event. In addition, a difference between muscle power of the dominant and non dominant arms may be a useful index to predict performances of sports competitors who use their upper limbs.

**Conclusions**

In conclusion, the dominant right hand has larger peak power in all loads for hand grip and in loads of 20-50%MVC for elbow flexion in both genders. The peak power ratio of the dominant right hand to the non dominant left hand was significantly larger in hand grip than in elbow flexion for all loads in females. Laterality is found in both hand grip and elbow flexion, but its gender difference is more marked in hand grip.
References
Table 1. Means of maximal hand grip and elbow flexion strength and results of ANOVA testing

<table>
<thead>
<tr>
<th></th>
<th>Male</th>
<th>Female</th>
<th>ANOVA(F-value)</th>
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<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
<td>F1</td>
<td>F2</td>
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<td>Hand grip</td>
<td></td>
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<tr>
<td>Dominant</td>
<td>47.2</td>
<td>4.1</td>
<td>32.6</td>
<td>3.0</td>
<td></td>
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<tr>
<td>Non dominant</td>
<td>42.6</td>
<td>3.3</td>
<td>27.7</td>
<td>2.4</td>
<td>190.13(p&lt;0.05)</td>
<td>84.25(p&lt;0.05)</td>
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<td>Elbow flexion</td>
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<tr>
<td>Dominant</td>
<td>32.3</td>
<td>1.6</td>
<td>21.0</td>
<td>1.4</td>
<td></td>
<td></td>
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<tr>
<td>Non dominant</td>
<td>30.1</td>
<td>1.4</td>
<td>19.1</td>
<td>1.4</td>
<td>446.60(p&lt;0.05)</td>
<td>168.04(p&lt;0.05)</td>
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Unit: Kg, Dominant: Dominant hand, Non dominant: Non dominant hand, F1: gender factor, F2: dominant and non dominant hand factor, F3: interaction
Figure 1-A Schematic of the device used to measure hand grip power

Figure 1-B Schematic of the device used to measure elbow flexion power
Figure 2. The mean peak power of hand grip movement by sex, load, and dominant/non dominant hands.
The bars show standard deviations.
Figure 3. The mean peak power of elbow flexion movement by sex, load, and dominant/non dominant arms. The bars show standard deviations.
Figure 4. The peak power ratio of the dominant hand to the non-dominant hand of hand grip and elbow flexion movements by sex and load. The bars show standard deviations.