Evaluation of Muscle Power Exerted by Explosive Gripping

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Abstract

Demura, S and Miyaguchi, K. Evaluation of muscle power exerted by explosive gripping. *J Strength Cond Res* 23(2): 465–471, 2009—To establish the evaluation method for muscle power exerted by explosive gripping, this study aimed to examine the reliability of parameters and the muscle power output properties in both genders. Fifteen young men and 15 women participated in this study. Each subject carried out explosive grip tests twice using a simple muscle power measurement device (weight loading method), each time with 20, 30, 40, and 50% loads of maximum grip strength (MGS) by isometric contraction. Peak power was drawn from the product of the measured peak velocity and relative loads. The reliability of each parameter in all loads was good (interclass correlation coefficient >0.75) for both genders. The MGS showed insignificant correlation with all parameters. Peak power values were larger in men than in women for all loads, and the women's values were 44.5–52.2% of the men's. A large gender difference was found for 20% MGS. In conclusion, the reliability of muscle power parameters measured by the measurement device in this study is high. It was judged that the device used in this study can properly evaluate the gender difference in muscle power output properties by explosive gripping.

Key Words explosive gripping, gender difference, rotary encoder, reliability, weight loading method

Introduction

Muscle power has generally been defined as the ability to produce high energy output within a very short period of time, and it is calculated from the product of force and velocity exerted during dynamic muscle contraction. Until now, muscle power has been evaluated using special measurement devices such as inertia wheels (10), isokinetic dynamometers (6,11), and the Cedaron Dexter System (14). Measurements obtained by these devices are quite objective and precise because of the relatively small contribution of the subject's skill factor. However, these devices are very expensive and large. Additionally, because of the need to give the subject a time restriction and the subsequent psychological stress for the subject, this measurement method is not necessarily simple or convenient. Hence, we used a simple and easy measuring device with a rotary encoder in this study to be able to measure even elderly and handicapped people easily. Using this device, we tried to measure the muscle power produced by explosive gripping.

In daily living, local muscle power involving a small range of joint motion, such as gripping or elbow flexion, is used more frequently than the explosive power of the whole body (1). In particular, grasp movements are very important and are used frequently in everyday life. Until now, gripping has been used to evaluate maximal grip strength (MGS) by isometric contraction. However, after muscle injury, even if maximum muscle strength is recovered sufficiently, it is often the case that the person can no longer exert muscle strength explosively. In addition, it was reported that under an isometric muscle contraction condition, the muscle output is influenced mainly by the cross-sectional area of the muscle and very little by the muscle fiber type (17). Hence, it will also be very important to evaluate the ability to exert force explosively (the rate of force development) by hand gripping in addition to the MGS. It was reported that the persistence of isometric muscle strength work with high intensity causes an elevation of blood pressure (16). The dynamic measurement method to exert muscle power instantly may, therefore, be more appropriate for muscle strength evaluation in the elderly.

When developing a new device, we need to confirm the reliability of the measurements. Demura et al. (4) tried to evaluate muscle power by force-time parameters exerted during explosive isometric gripping. They reported that the interclass correlation coefficient (ICC) of the maximal grip value was more than 0.9, but the ICC of the force-time parameters was lower than 0.7. The measurement device used in this study can measure muscle power from performances (moving velocity) exerted with a form similar to real output properties.

Thus, it is considered that this device is practical and offers more reliable data than other devices. In fact, Demura et al. (3)

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measured elbow flexure power using this device and report that the reliability of measurements was very high (ICC = 0.89). However, the reliability of measurements from local small movements, such as gripping, has not yet been sufficiently examined.

Additionally, many researchers have reported that even though the maximal strength was the same, individual differences and gender differences were found in the developmental phase (the initial phase until reaching the maximum force) of the force-time curve during isometric explosive strength exertion (19). Hence, examining the relationships between power evaluation parameters obtained by the present device and MGS by isometric contraction and the output power properties of genders will be important in the future for evaluating the gripping power of people of a wide age range, including the elderly.

To establish the evaluation method of muscle power exerted by explosive gripping, this study aimed to examine the reliability of parameters and the muscle power output properties in both genders.

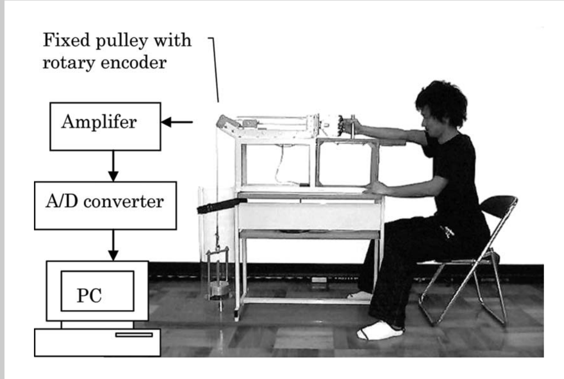

Figure 1. Schematic representation of experimental setup.

Methods

Experimental Approach to the Problem

In this study, each subject carried out explosive grip tests twice using a simple muscle power measurement device (weight loading method), each time with 20, 30, 40, and 50% loads of MGS by isometric contraction. Peak power was drawn from the product of the measured peak velocity and relative loads. The reliability of parameters and the muscle power output properties in both genders were examined.

Subjects

The subjects were 15 young men (mean age 22.2 ± 2.4 years, mean height 172.2 ± 4.9 cm, mean weight 66.5 ± 9.8 kg) and 15 women (mean age 21.4 ± 2.3 years, mean height 162.1 ± 8.0 cm, mean weight 55.5 ± 5.5 kg). Informed consent was obtained from all subjects after a full explanation of the experiment and its procedures. The study was approved by the human rights committee of Kanazawa University.

Experimental Device and Muscle Power Measurement

Isotonic muscle power exerted by explosive gripping with relative loads (20–50% MGS) was measured by a muscle power measurement device (Yagami, Japan) using the weight loading method, which can measure velocity when moving constant loads (Figure 1). This device consists of a rotary encoder (SUNX, ORE38-1200) attached to a fixed pulley and a recording device. The encoder measures the rotational angle with a sampling frequency of 100 Hz via an analog-to-digital interface. The resolution of rotary encoder is 1200 pulses per turn. In short, a pulse occurs every 0.3°, and the device calculates the angle of rotational degree (0.3 × pulses) by counting the incidence of a pulse. The rotational angle was converted to the moving velocity of the load in the recording device. If muscle contraction velocity using a rotary

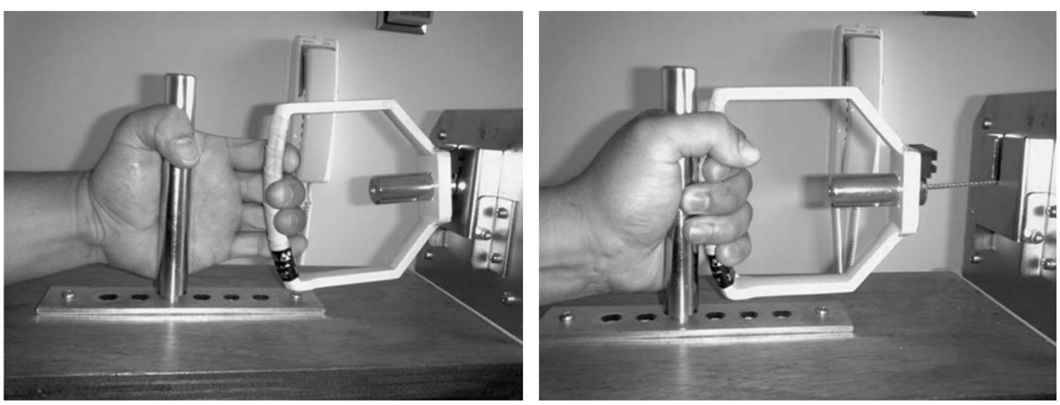

Figure 2. Grip power measurement position (start: left; finish: right).

Figure 3. Attachment for gripping.

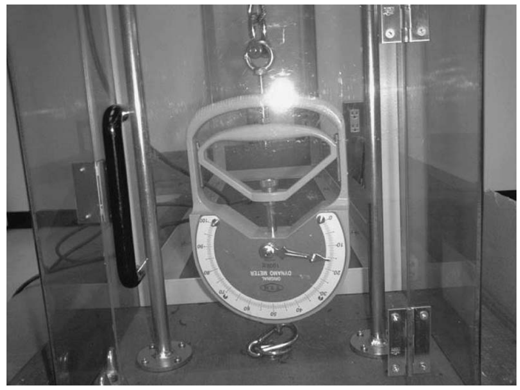

Figure 4. Dynamometer for measuring maximal voluntary grip contraction.

encoder can be precisely measured, muscle power also can be adequately measured by small grasp work.

Each subject attached his or her palm to the fixed bar, grasping the handle with 4 fingers and not the thumb, and then explosively pulled the handle to the fixed bar as shown in Figure 2. The amount of work produced by gripping was assessed by the moving distance (about 5–7 cm). 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 semiprone position. The use of an armrest ensures that the measured values of this study are not influenced by the weight of the device and any swinging of the arm with the device (Figure 3). Subjects can instead concentrate on explosive gripping. The height of the seat was adjusted with consideration of each subject's height.

The grip width could be arbitrarily adjusted for each individual by a dial to achieve a 90° angle with the proximal-middle phalanges. Peak velocity and velocity-time curves were measured by the device (weight loading method) when pulling loads quickly by explosive gripping. Peak power was drawn from the product of the peak velocity and relative loads based on Newton's second law of motion. The formula for computation of muscle power was as follows:

Peak power (W) = load mass (kg) × acceleration of gravity (9.807 $m \cdot s^{-2}$) × peak velocity ($m \cdot s^{-1}$)

Additionally, to clarify the muscle power output properties during explosive gripping, the power curve was determined by multiplying the velocity time-series data by each load mass.

Experimental Procedure

Before an experiment, the height and body weight of each subject were measured. To determine the relative loads for the power test, subjects performed the MGS test with the dominant hand, determined based on Oldfield's (15) handedness inventory, twice before the power test, and the higher value was designated as the MGS. The MGS was measured using a Smedley-type grip strength dynamometer attached to the end of a wire rope (Figure 4). The load was selected as 20, 30, 40, and 50% of MGS based on previous studies (18). The experiment was done with a crossover design so that every volunteer performed each test twice on the same day. Subjects were instructed to exert maximal force as fast and

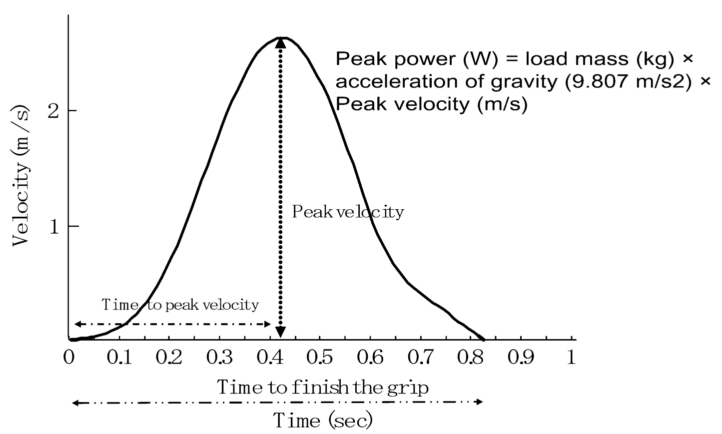

Figure 5. Velocity-time curve and parameters.

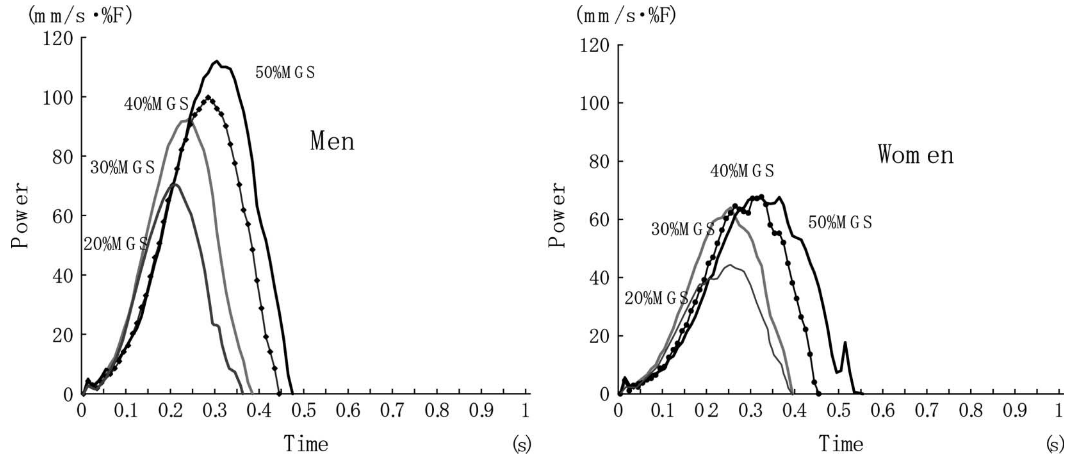

Figure 6. Average curve of peak power in the power grip test.

forcefully as possible immediately after hearing a beeping sound from the instrument. They conducted several practical trials to get accustomed to the device and to explosive gripping.

Evaluation Parameters

The following muscle power parameters were selected by referring to previous studies (5) (Figure 5): peak velocity during 0.01 seconds (mm·s^{-1}), time to peak velocity (seconds), time to finish the grip (seconds), average velocity to finish (mm·s^{-1}), and peak power (W). Peak power was calculated from the product of the peak velocity and relative load based on MGS.

Statistical Analyses

Examination of Reliability. A cross-correlation coefficient is a time-series correlation coefficient and is calculated to examine the concordance of both wave forms/fluctuations. In this study, to examine the trial-to-trial reproducibility of a series of power curves, cross-correlation coefficients were

Table 1. Mean of parameters in each load and correlation with maximum grip strength.

			Men				Women			
	Parameters	Unit	M	*SD*	CV	*r*	M	*SD*	CV	*r*
20%	Time to peak velocity	s	0.20	0.04	17.99	0.07	0.27	0.06	23.03	0.34
	Time to finish the grip	s	0.33	0.04	11.43	−0.32	0.38	0.10	25.49	0.08
	Average velocity	m m /s /s	1.92	0.21	10.98	−0.01	1.34	0.33	24.36	−0.14
	Peak power	m m / s %	81.20	9.99	12.30	−0.17	59.67	17.94	30.06	−0.11
30%	Time to peak velocity	s	0.25	0.04	15.74	−0.12	0.30	0.07	22.98	0.11
	Time to finish the grip	s	0.36	0.05	13.23	−0.33	0.41	0.12	29.64	−0.08
	Average velocity	m m /s /s	1.61	0.23	14.21	0.26	1.22	0.33	27.22	0.06
	Peak power	m m / s %	97.90	13.65	13.94	−0.02	80.50	22.15	27.52	−0.03
40%	Time to peak velocity	s	0.29	0.05	16.50	−0.23	0.35	0.09	24.89	**0.63**
	Time to finish the grip	s	0.43	0.06	13.24	−0.17	0.49	0.12	25.46	0.39
	Average velocity	m m /s /s	1.43	0.20	14.60	−0.18	1.03	0.30	28.86	−0.29
	Peak power	m m / s %	110.40	15.69	14.22	−0.07	95.47	31.07	32.54	−0.12
50%	Time to peak velocity	s	0.32	0.05	15.37	−0.07	0.38	0.11	27.73	**0.62**
	Time to finish the grip	s	0.49	0.07	15.19	−0.23	0.57	0.18	31.40	0.25
	Average velocity	m m /s /s	1.17	0.25	20.91	0.12	0.88	0.26	29.82	−0.31
	Peak power	m m / s %	120.83	31.03	25.68	0.03	96.83	28.25	29.17	−0.19

CV = coefficient of variation. Bold text of ICC indicate significant correlations ($p < 0.05$).

calculated between time-series data for each relative load. The ICCs of parameters regarding muscle power were calculated to examine the trial-to-trial reliability.

Examination of Gender Difference. The relationships between muscle power parameters and MGS were examined using the Pearson correlation coefficient. Two-way analysis of variance (ANOVA) was used with groups (men and women) as the between-subjects factor and load condition (20, 30, 40, and 50% MGS) as the repeated measures. Multiple comparisons were performed using the Tukey HSD method. The probability level was set a priori at $p \leq 0.05$ to determine statistically significant differences.

Results

Reliability of Measurements

Figure 6 shows the time-series average power curves exerted by each load for men and women. The cross-correlation coefficients between trials were larger than 0.95 in both genders. Table 1 shows the means of the evaluation parameters and the coefficient of variation (CV) for each load. The CV values were larger in women than in men for all loads. The ICCs were very high (above 0.75) except for the cases of time to peak velocity and average velocity of 30% MGS in men (men: 0.77–0.92; women: 0.77–0.98).

Properties of Muscle Power Exertion in Men and Women

To clarify muscle power output properties in both genders during explosive gripping, peak power was drawn from the product of the measured peak velocity and relative loads. As the load increased, the time to finish gripping became longer in both genders (Figure 4). Peak power tended to become higher with increased load in men, but not in women. The MGS showed insignificant correlation with any parameter except for the time to peak velocity of 40 and 50% MGS in women (Table 1).

Figure 7 shows a change of peak velocity and power in both genders for each load and 2-way ANOVA results. Peak velocity values were larger in men than in women at 20, 30, and 50% MGS, and a large gender difference was found in 20% MGS but not in 40% MGS. Peak power values were larger in men than in women for all loads, and the women's values were 44.5–52.2% of the men's. Peak power tended to increase with increasing loads in both genders, but it showed an insignificant difference between 40 and 50% MGS in women.

Discussion

An isokinetic dynamometer, which is a current standard device among muscle power measurement devices, can control accelerated velocity and measure the power exerted while maintaining constant velocity. On the other hand, the measurement device used in this study can measure muscle power from performances (moving velocity) exerted with a form similar to real output properties. Because this device can measure time-series power output with high accuracy, the force rising development phase in ballistic muscular contraction with maximum effort can be analyzed. However, the gripping motion in this study involves multiple joints with a very small range of motion and is different from large movements at a simple joint, such as elbow flexion and knee extension. Hence, we have to examine the reliability of dynamic muscle power values given by explosive gripping.

The reproducibility of isotonic muscle power exerted by explosive gripping is considered to be high from the present results (>0.95) in both genders. Miyaguchi and Demura (13) measured elbow flexion power by the presence or absence of countermovement using a device of the same type and have reported that cross-correlation coefficients were significant

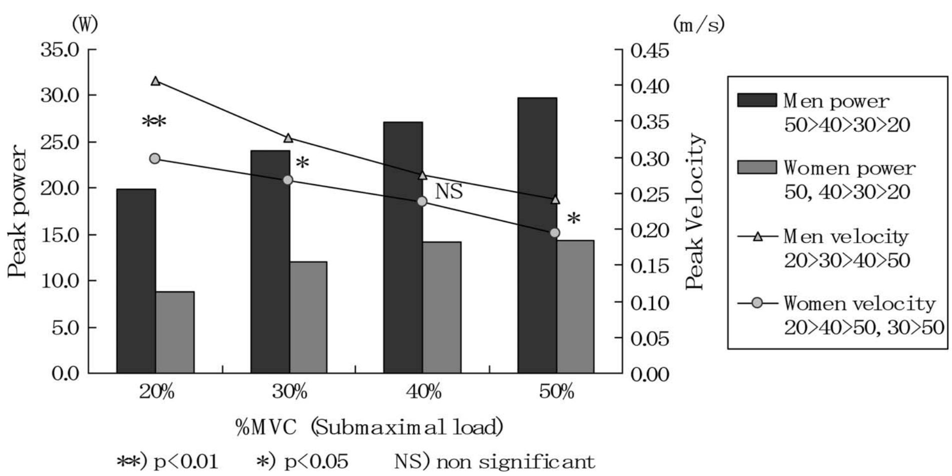

Figure 7. Change of peak power and peak velocity with relative loads for both genders.

and high ($r = 0.75$–0.99) in any condition. The above values exceed them. Perhaps because subjects were accustomed to gripping rather than elbow flexion or knee extension, stable muscle power exertion might have been possible. Because explosive gripping is a movement with a small technical factor, high reliability can be also expected in the measurement of women and the elderly.

Until now, attention has been paid to only MGS in general grip strength exerted by isometric contraction, but Demura et al. (4) tried to evaluate muscle power by force-time parameters exerted during explosive isometric gripping. They report that the ICC of the maximal grip value was more than 0.9, but the ICC of the force-time parameters was lower than 0.7. The present ICCs were high values >0.75. Thus, measurements of muscle power exertion by explosive gripping may have higher reliability than those of isometric muscle power exertion. The movement range of gripping was small. In addition, subjects can exert power with almost the same conditions as a real movement style (output properties). From the above reason, ICCs may have been high values.

On the basis of the insignificant correlations between MGS and each parameter in both genders, we speculate that the parameters selected in this study reflect a different myofunction from MGS. Namely, the present measurement device can evaluate the property of muscle power that a traditional device cannot evaluate.

The peak velocity showed larger values in men than in women at 20, 30, and 50% MGS but not at 40% MGS. Kaneko (8) reports that muscle contraction velocity does not show a gender difference as large as maximal muscle strength. The present results using 4 kinds of relative loads suggest that the muscle contraction velocity at 40% MGS is very similar between men and women. From the above result, we can conclude that using the 40% MGS, which shows an insignificant gender difference in peak velocity, may be effective when comparing the output properties of muscle power (the rate of force development) between men and women.

On the other hand, a marked gender difference was observed in peak velocity at 20% MGS. This may result from a gender difference of muscle contraction velocity because of the lightweight load (high speed). Kanehisa et al. (7) examined a gender difference in the dynamic muscular strength of speed skate players and the general population and have reported that although a significant gender difference was not found in the value of muscular strength per cross-sectional area at $60°\cdot s^{-1}$, men showed higher values than women at 180 and $300°\cdot s^{-1}$. Hence, even if gender differences in muscle mass are controlled for, men will still be superior in muscle power output at high speed.

As the loads increased, the peak power tended to increase in men, whereas in women a significant difference was not found between 40 and 50% MGS. Kaneko (9) has reported that peak power is generally found at one-thirds MGS in the case of simple muscle power output effort. However, the relative intensity producing the maximum power differs largely based on the movement pattern or physical region. From the present results, peak power may have been exerted in load settings with 50% MGS or more for men and at 40% MGS for women. The above problem should be examined in detail in the future.

It has been reported that a strength factor generally shows a larger gender difference than a muscle contraction velocity factor and that a woman's muscle power is around 50–60% that of a man's (2,12). The women/men ratio of peak power was somewhat low (44–52%) in comparison with the above. Muscle power is mainly measured by simple joint movement. However, the gripping movement used in this study is a complicated multijoint movement, despite producing a small local movement. This difference may be related to the low gender ratio.

In conclusion, peak power values by explosive gripping were larger in men than in women for all loads, and the women's values were 44.5–52.2% of men's. A large gender difference was found in 20% MGS. The reliability of muscle power parameters measured by a simple measurement device in this study is high. It is judged that the device used in this study can properly evaluate a gender difference in muscle power output properties by explosive gripping.

Practical Applications

Through muscle power measurement using explosive gripping, we have examined the gender difference of output properties that we could not evaluate by the conventional grip measurement. Because explosive gripping is a movement with a small technical factor, high reliability can also be expected in the measurement of women and the elderly. It might be possible to examine grip power properties in detail by measuring 0.1-second power to evaluate the initial situation that Demura et al. (3) have noted in elbow flexion.

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