Sex Differences in Kinematics and Quadriceps Activity for Fast Isokinetic Knee Extension

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빠른 속도의 무릎 폄에서의 넙다리네갈래근의 활동과 운동학에서 성별의 차이

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Abstract

The aim of this study is to make a comparison between the isokinetic parameters, isokinetic phases, and muscle activities according to velocity and sex to determine the consideration of isokinetic exercise. A total of 41 healthy adults performed concentric knee extension at angular velocities of 60°/s, 180°/s, and 240°/s. The isokinetic parameters (peak torque (PT), peak torque per body weight (PT/BW), total work, and power), and isokinetic phase (acceleration, load range, and deceleration) were measured. Muscle activity during isokinetic contractions in rectus fermoris, vastus lateralis, and vastus medialis was measured using electromyography. There were significant two-factor main effect and interaction between sex and angular velocity on the power of knee extension and isokinetic phase ($p<0.05$). As the velocity increased, the increas in power of males was greater than that of females. In contrast, with the increase in velocity, PT,PT/BW, and total work decreased, but no significant interaction was observed between velocity and sex. At high velocity, males showed higher acceleration ability than females. The sex-dependent responses to velocity were more affected by differences in total movement time than force production. Fast isokinetic exercise should consider the acceleration ability rather than the ability to produce force.

Keyword: isokinetic contracrion, sexual difference, fast speed, acceleration phase, knee biomechanics

1. Introduction

The Physical parameters associated with the task performance include speed of movement, resistance, distance moved, and the number of repetitions [1]. The maximum resistance applied in isotonic exercise is the load at the weakest point in the entire range of motion [2]. Isokinetic exercise is a method for fixing the maximum velocity, which in theory produces the maximum force throughout the active range of motion [1,3]. To explain the decrease in muscle activity with increasing velocity, these hypotheses were adopted. The first explanation is either facilitator or inhibitor effect on the motor neuron pool because the proprioceptive feedback is velocity dependent. However, this explanation has contradictions that can explain both the increase and decrease in torque or/and muscle activity. An alternative explanation is that the qualitative recruitment of motor units with different functional properties is determined by specific demands. Conversely, there was a result of the neural inhibitory mechanism as an explanation for the increase in muscle activity with increasing velocity [4,6,7].

The recruitment of more motor units and a higher firing rate results in increased EMG amplitude [8]. These sex-related differences affected the fiber type composition [9]. Because of biopsy for the vastus lateralis (VL) muscle, the distribution ratio of slow oxidative fibers was high in females. The percentages of the fast glycolytic fiber were high in male VL muscle. However, it had different mechanisms for force production based on movement velocity [10-12]. Therefore, it is necessary to study the response of muscle activity according to the velocity of the isokinetic movement through a comparison between males and females with different muscle fibers' composition.

This study aims to compare the change in the isokinetic parameters (PT, peak torque per body weight (PT/BW), total work, and power), isokinetic phases (acceleration (ACC), load range (LR), and deceleration (DEC)), and quadriceps muscle activity (rectus femoris (RF), vastus lateralis (VL), and vastus medialis (VM)) based on sex and velocity and to investigate the correlation between muscle activity and isokinetic data.

2. Method

2.1 Participant

A total of 41 healthy young adults, 20 males (age 23.85 ± 2.13 years, weight 72.45 ± 9.21 kg, height 174.2 ± 4.46cm) and 21 females (age 22.43 ± 1.83, weight 56.90 ± 13.45, height 160.62 ± 5.43 cm), were included in this study. They were free from the pain that could influence the movements performed in this study. This study was approved by the Institutional Review Board of Sunmoon University (SM-201910-059-1).

The isokinetic dynamometer (HUMAC NORM Testing and Rehabilitation System, CSMI Medical Solutions, Stoughton, MA) was used to collect the isokinetic data of knee extensors of the dominant leg. All participants performed 3 repetitions of concentric maximal contraction for knee extension at randomly ordered velocities of 60°/s, 180°/s, and 240°/s.

2.2 Isokinetic measurement

An isokinetic test of the knee extension was performed to acquire the data of the isokinetic parameters (PT, PT/BW, total work, and power) and isokinetic phases (ACC, LR, and DEC). The PT was normalized for BW (Nm/kg). The PT/BW is used to compensate for individual differences related to weight [13]. The isokinetic concentric contraction involves three phases including ACC, constant velocity, and DEC [5,14]. The ACC phase represents reaching a preset velocity and is performed without resistance. Constant velocity, known as the LR, is the phase in which the mechanical speed and the individual's movement velocity correspond. The DEC phase is the phase in which the movement stops as the velocity decreases after LR. The ratio of time for each phase to total movement time (% total movement time) was calculated and used for analysis.

2.3 Electormyography

The muscle activity in RF, VL, and VM during isokinetic contractions was measured using wireless surface EMG system (Zerowire EMG, Aurion, Italy). The EMG data for each participant were normalized using the maximal voluntary isometric contraction (MVIC) test. An isokinetic dynamometer was used for the MVIC test, and the participants' knee joint and hip joint were maintained at 60° and 90° flexion, respectively [9-18]. In 3 MVIC tests, a 5 s EMG signal was measured for the knee extension motion. The average values for the middle 3 s of each muscle were calculated. Participants were given a 1 min break between each test.

The sampling frequency for the EMG was 1000 Hz. MyoRESEARCH software (XP Master, version 1.07.1, Noraxon, Scottsdale, AZ, USA) was used to analyze raw data from EMG. The signal was filtered using a bandpass filter between 20 and 450 Hz. Using the root mean square (RMS) with a 10 ms window, the filtered signal was full wave rectified and smoothed. Subsequently, all EMG amplitude values obtained during the isokinetic test were normalized to the corresponding muscle's MVIC (MVIC %).

2.4 Statistical analysis

The isokinetic parameters, isokinetic phases, and EMG values were averaged over three trials and used for analysis. The effect of sex and angular velocity on isokinetic parameters, isokinetic phases, and muscle activity was assessed using a two-way analysis of variance (ANOVA) using SPSS software (SPSS 22.0, SPSS Inc., Chicago, IL, USA). When a significant two-factor interaction or the main effect was observed, Tukey's HSD was conducted as a post hoc test. The variables between sex were compared using an independent t-test (Student t-test). The associations between the mean EMG value of quadriceps in microvolts (RMS) and isokinetic measures during isokinetic exercise were determined using Pearson's product-moment correlation. The level of statistical significance was set at a P value < 0.05.

3. Result

There were significant two-factor main effect and interaction between sex and angular velocity on the power of knee extension and isokinetic phase ($p<0.05$) [Table 1]. As the velocity increased, the increase in power of males was greater than that of females. In contrast, with the increase in velocity, PT,PT/BW, and total work decreased, but no significant interaction was observed between velocity and sex. At high velocity, males showed higher acceleration ability than females. at 60°/s.

Table 1. Differences in isokinetic parameters according to sex (male and female) and angular velocity (60°/s, 180°/s, and 240°/s) during isokinetic exercise

Isokinetic parameters		Angular velocity(°/s)		
		60	180	240
PT(Nm)	Male	140.31 ± 41.88	88.35 ± 27.59	74.65 ± 20.99
	Female	92.29 ± 29.43	47.05 ± 15.71	35.25 ± 12.54
PT/BW(Nm/kg)	Male	1.96 ± 0.61	1.23 ± 0.39	1.04 ± 0.31
	Female	1.62 ± 0.37	0.83 ± 0.26	0.63 ± 0.23
Total work(J)	Male	309.20 ± 103.93	212.10 ± 82.19	173.65 ± 61.02
	Female	225.10 ± 77.14	113.43 ± 43.57	74.60 ± 34.25
Power(Watt)	Male	69.40 ± 20.86	110.90 ± 48.45	106.25 ± 44.84
	Female	50.10 ± 16.28	62.90 ± 23.93	53.80 ± 21.52

Values are presented as mean ± standard deviation. PT: peak torque, BW: body weight. Significant differences are indicated in bold ($P < 0.05$).

Table 2. Comparison of quadriceps muscle activity, traditional isokinetic parameter, and isokinetic period during isokinetic exercise between males and females

Angular velocity	Variables		Male	Female	P value
60°/s	Muscle activity (%MVIC)	RF	68.99 ± 14.12	80.34 ± 13.72	0.013*
		VL	68.93 ± 16.95	78.51 ± 15.13	0.063
		VM	69.99 ± 15.44	76.78 ± 14.55	0.155
	Traditional isokinetic parameter	PT(Nm)	140.31 ± 41.88	92.29 ± 29.43	<0.001*
		PT/BW(Nm/kg)	1.96 ± 0.61	1.62 ± 0.37	0.042*
		Total work(J)	309.20 ± 103.93	225.10 ± 77.14	0.006*
		Power(watt)	69.40 ± 20.86	50.10 ± 16.28	0.002*
	Isokinetic period(% total movement time)	ACC	14.91 ± 1.13	15.47 ± 0.87	0.084
		LR	74.33 ± 2.18	73.73 ± 1.81	0.341
		DEC	10.76 ± 1.64	10.80 ± 1.77	0.932
180°/s	Muscle activity (%MVIC)	RF	63.63 ± 18.12	62.49 ± 15.66	0.831
		VL	70.88 ± 19.22	71.81 ± 17.61	0.873
		VM	71.97 ± 17.37	71.01 ± 20.21	0.871
	Traditional isokinetic parameter	PT(Nm)	88.35 ± 27.59	47.05 ± 15.71	<0.001*
		PT/BW(Nm/kg)	1.23 ± 0.39	0.83 ± 0.26	0.001*
		Total work(J)	212.10 ± 82.19	113.43 ± 43.57	<0.001*
		Power(watt)	110.90 ± 48.45	62.90 ± 23.93	<0.001*
	Isokinetic period(% total movement time)	ACC	47.65 ± 3.72	50.91 ± 3.99	0.010*
		LR	23.87 ± 4.21	22.24 ± 3.86	0.202
		DEC	28.48 ± 4.93	26.86 ± 5.07	0.307
240°/s	Muscle activity (%MVIC)	RF	61.82 ± 21.46	51.95 ± 16.08	0.108
		VL	71.18 ± 18.44	61.92 ± 14.57	0.086
		VM	71.93 ± 16.81	62.44 ± 17.53	0.089
	Traditional isokinetic parameter	PT(Nm)	74.65 ± 20.99	35.25 ± 12.54	<0.001*
		PT/BW(Nm/kg)	1.04 ± 0.31	0.63 ± 0.23	<0.001*
		Total work(J)	173.65 ± 61.02	74.60 ± 34.25	<0.001*
		Power(watt)	106.25 ± 44.84	53.80 ± 21.52	<0.001*
	Isokinetic period(% total movement time)	ACC	49.85 ± 4.91	57.15 ± 4.93	<0.001*
		LR	14.01 ± 4.22	11.43 ± 3.27	0.038*
		DEC	36.15 ± 5.43	31.41 ± 4.86	0.006*

4. Discussion

This study provides considerations for effective isokinetic exercise. It is necessary to check the increase in power rather than the decrease in torque that accompanies the higher velocity to achieve effective isokinetic exercise. The higher power is closely related to the explosive momentary ACC ability. The torque production capacity at a relatively slow or moderate velocity is highly concerned with muscle activity of VM and VL regardless of sex and velocity. At a relatively high velocity, muscle activity of the RF is required. Further studies are needed to investigate the change of momentary ACC capacity according to the application of repetitive fast isokinetic exercise. The results of this study showed that participants with high muscle activity had a high torque production capacity at all velocities. Therefore, we consider that there is a correlation between muscle activity and torque generation, regardless of sex and velocity during isokinetic exercise. Furthermore, previous conflicting evidence might be due to differences in experimental conditions, as well as differences in response to velocity among individuals.

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