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Original Article

Kinematic Characteristics of the McKenzie Exercise in Healthy Older Males

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Abstract. [Purpose] The purpose of this study was to clarify the kinematic characteristics in older males performing the prone, puppy, and extension in lying positions used in the McKenzie exercises. [Methods]The participants were 22 males over 65 years old. Muscle thickness of the right lumbar multifidus muscle at L2 and L5 and the right erector spinae muscle were measured using ultrasonography. Sacral inclination and lumbar lordosis angles were measured using a devise called the Spinal Mouse. Measurements of muscle thickness and spinal angles were compared between the three positions. [Results]The thickness of the back muscles increased significantly in the extension in lying position compared to the prone position. The lumbar lordosis angle increased significantly in the puppy and extension in lying positions compared to the prone position. The sacral inclination angle decreased significantly as subjects moved from prone to puppy to extension in lying positions. [Conclusion]These results suggest that while both the puppy and extension in lying positions improved the mobility of the lumbar spine, only the extension in lying position changed the shape of the back muscles.

Key Words: McKenzie exercises, ultrasonography, muscle shape, Spinal Mouse, mobility of the spine

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1. INTRODUCTION

The McKenzie exercises are widely used by physical therapists throughout the world for the assessment and treatment of low back pain. A survey of 120 physical therapists in the United States reported the McKenzie exercises as the most widely used assessment method of low back pain[1)], and a survey of 1548 physical therapists in Ireland found the McKenzie exercises to be the most widely used treatment method for low back pain[2)]. Low back pain is often associated with a reduction in spinal mobility[3)] and changes in muscle activity[4, 5)]; therefore, training with the McKenzie exercises in which spinal extension is performed in prone, puppy, and extension in lying positions has been shown to improve back pain[6, 7)].

While the mechanism of spinal pain reduction induced by the McKenzie exercises is unclear, there are two approaches to low back pain recovery that could be considered. First, back pain relief can be a result of morphological changes in the facet joints or lumber multifidus muscle. When the lumbar spine is extended, the inferior articular process moves downward and the entire facet joint is compressed. It has been reported that the joint capsule of the facet joint has many free nerve endings that sense pain and that the same spinal nerve passes through both the lumbar facet joint and the surrounding lumbar multifidus muscle[8)]. Therefore, stimulation to the facet joints and lumbar multifidus muscles due to lumbar extension may lead to relief of low back pain. Second, back pain relief can result from morphological changes to the lumbar disk. When the lumbar spine is extended, the nucleus pulposus of the lumbar disk moves anteriorly[9)] and away from the nerve, which decreases nerve compression and subsequent back pain. However, at present, there is no research to show that low back pain is alleviated by these mechanisms.

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Clarifying the kinematic characteristics of spinal mobility and muscle activity could effectively elucidate the mechanism of low back pain relief achieved by performing the prone, puppy, and extension in lying positions. Previous research examining the kinematic features of the prone, puppy, and extension in lying positions evaluated the lumbar lordosis angle in healthy young females using X-ray images[10] and found that lumbar lordosis increased significantly in the extension in lying position compared to the prone and puppy positions but that there was no significant difference in lordosis between the prone and puppy positions. Since we could find no research that examined the spinal mobility and muscle form of older male subjects in the prone, puppy, and extension in lying positions, and since spinal mobility is reduced with age [11, 12] and lesser in males than in females[11, 13], we surmised that performing this study using older male subjects could produce different results. Therefore, the purpose of this study was to clarify the kinematic characteristics of spinal mobility and muscle activity in older males when performing the prone, puppy, and extension in lying positions used in the McKenzie exercises.

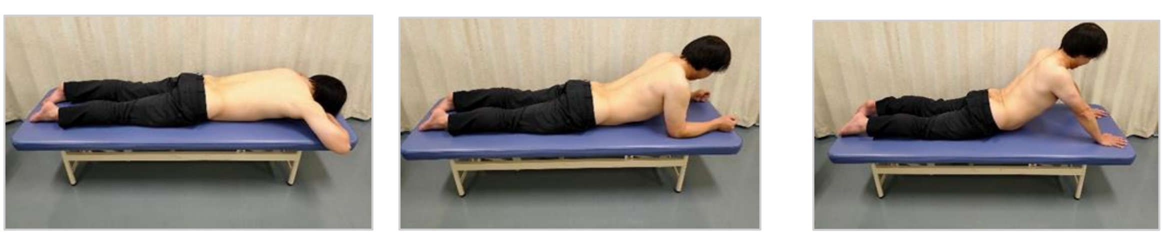
2. SUBJECTS AND METHODS

1.Participants

This study included 22 males over the age of 65 (mean age, 70.8 ± 4.6 years; mean body mass index [BMI], 23.3 ± 2.4 kg/m^2) who were dispatched from a staffing agency specializing in an older demographic. All participants lived independently were independent walkers (able to walk at least 50 m unaided), and had not undergone any surgical procedures within the previous six months. Exclusion criteria were illness, injury, pain in the waist or abdomen, or previous low back pain. The study was conducted in accordance with the Declaration of Helsinki, and the protocol was approved by the Ethics Committee of the International University of Health and Welfare Hospital (20-Io-52). The purpose and details of the study were explained to the participants beforehand, and the authors declared no conflicts of interest.

2.Positioning

All positions in this study are shown in figure 1. Each participant underwent measurements of spinal mobility and muscle shape in the prone, puppy, and extension in lying positions. For the prone position, the participant lay face down with hands together in front of the forehead. For the puppy position, the participant extended his upper body from the prone position by pushing into the forearms, keeping the navel in contact with the horizontal supporting surface. For the extension in lying position, the participant extended his upper body by pushing into the palms of the hands until elbows were fully extended. Participants were instructed to relax completely in each position, and each posture was practiced three times to ensure posture reproducibility. The measurement site was exposed to the outside to facilitate the measurement. Positions were held less than 30 seconds to minimize fatigue, and participants were given a one minute break between measurements.



The prone The puppy The extension in lying

Figure 1 Measurement positions

3.Spinal mobility measurement

A Spinal Mouse (Index Corp, Idiag, Fehraltorf, Switzerland) was used to measure the sacral inclination angle (positive lordosis, negative kyphosis) and the lumbar lordosis angle (negative lordosis, positive kyphosis). The validity of using the Spinal Mouse to measure spinal mobility has been demonstrated via X-ray comparison[14)], and the intraclass correlation coefficients have reported good reliability[15–17)]. The measurement device was guided along the midline of the spine from the spinous process of C7 to S3. For measurement reproducibility, the spinous process was marked with an oily pencil, and spinal mobility in each position was measured twice and averaged together.

4.Muscle activity measurement

Muscle activity can be examined by observing changes in muscle thickness using ultrasonography[18)]. Ultrasound imaging devices are advantageous because they can observe deep muscles but do not require needle insertion into muscles like electromyography does. The validity of muscle activity obtained by ultrasonography has been proven comparable to measurements obtained by both electromyograms[18–20)] and magnetic resonance imaging (MRI)[21)]. Furthermore, the intraclass correlation coefficients have reported good reliability[22, 23)]. Referring to a previous study that regarded changes in muscle thickness by posture as muscle activity[24)], this study measured the muscle thickness of the right lumbar multifidus muscle at L2 and L5 and the right erector spinae muscle using ultrasonography (sonosite 180 plus: sonosite Ltd.). Based on previous studies[25–27)], muscle thickness of the lumbar multifidus muscle at L2 and L5 was measured 2 cm outside of each spinous process with the probe placed perpendicular to the spinal column. Also based on previous studies[23, 26)], the muscle thickness of the erector spinae muscle was measured 5 cm outside of the spinous process of the third lumbar vertebra with the probe placed perpendicular to the spinal column. For measurement reproducibility, the spinous process was marked with an oily pencil. Measurements were performed at the end of expiration, and the muscle thickness was calculated using pictures obtained via ImageJ (U.S. National Institute of Health). Muscle thickness in each position was measured twice and statistics were calculated using the average value.

5.Data analysis

The Shapiro–Wilk test was used to check the normality of age, BMI, and muscle thickness in each position. The mean ± SD was calculated for all variables. A one-way analysis of variance and the Bonferroni test were used to examine differences in muscle thickness and spinal mobility in each position. SPSS software version 19.0 (IBM, Tokyo, Japan) was used for all data analyses. The level of significance was set at 5%.

3. RESULTS

All values obtained in this study are shown in Table 1.

Table 1 Back muscle thickness and spine mobility for each posture (n = 22)

		Prone	Puppy	Extension in lying
Back Muscle Thickness	Erector Spinae (mm)	$30.0 \pm 3.8^{\dagger}$	$30.4 \pm 4.5^{\dagger}$	$32.9 \pm 6.3^{*,\#}$
	Lumbar Multifidus (L2, mm)	$30.2 \pm 4.8^{\dagger}$	31.8 ± 5.6	$33.8 \pm 5.1^{*}$
	Lumbar Multifidus (L5, mm)	$30.7 \pm 5.4^{\dagger}$	$30.8 \pm 4.7^{\dagger}$	$33.6 \pm 4.9^{*,\#}$
Spine Mobility	Lumbar lordosis angle (°)	$-15.2 \pm 11.2^{\#,\dagger}$	$-23.1 \pm 8.2^{*}$	$-21.6 \pm 9.3^{*}$
	Sacral inclination angle (°)	$91.4 \pm 5.8^{\#,\dagger}$	$79.7 \pm 7.2^{*,\dagger}$	$60.5 \pm 7.7^{*,\#}$

*: $p < 0.05$ (vs prone), #: $p < 0.05$ (vs puppy), †: $p < 0.05$ (vs extension in lying)

1.Spinal mobility measurement

The sacral inclination angle and the lumbar lordosis angle showed main effects. The lumbar lordosis angle was increased significantly in both the puppy and extension in lying positions compared to the prone position and showed no significant difference between the puppy and extension in lying positions. The sacral inclination angle decreased significantly as the subject moved from the prone to the puppy to the extension in lying positions, in that order.

2.Muscle activity measurement

The muscle thickness of the lumbar multifidus muscle at L2 and L5 and the erector spinae muscle showed main effects. The thickness of all the back muscles increased significantly in the extension in lying position compared to the prone position, however, there was no significant difference in back muscle thickness between the prone and puppy positions. Additionally, the muscle thickness of the erector spinae muscle and the lumbar multifidus muscle at L5 increased significantly in the extension in lying position compared to the muscle thickness in the puppy position.

4. DISCUSSION

The purpose of this study was to clarify the kinematic characteristics of spinal mobility and muscle activity in older males when performing the prone, puppy, and extension in lying positions used in the McKenzie exercises and to elucidate the mechanism of back pain relief.

Our results suggest that the different positions cause changes in the spinal curvature angle and muscle thickness. We found that the lumbar lordosis angle increased significantly in the puppy and the extension in lying positions compared to that in the prone position, but there was no significant difference in the lumbar lordosis angles between the puppy and the extension in lying positions, inferring that the lumbar lordotic angle was maximized in the puppy position. As expected, our results are different from the prior research[10)], whichused X-rays to measure the lumbar lordosis angle in the same three positions and found no significant difference in angles between the prone and the puppy positions[10)], but a significantly increased lumbar lordotic angle in the extension in lying position compared to that of the prone and puppy positions. However, the participants in our study were older males while the participants in that previous study were young females[10)], and it has been reported that age and gender affect the flexion and extension movements of the lumbar spine[28)].

A study by Song and Qu[29)] demonstrated that spinal mobility is reduced in elderly people compared to their younger counterparts. By investigating the age-related biomechanical differences during lifting, they showed that older adults adopted safer lifting strategies than younger adults, specifically with regard to the peak trunk sagittal flexion and the peak trunk transverse twisting angles, which were lower in older adults than in younger adults. In addition, a study by Kienbacher et al.[11)] revealed that spinal mobility is reduced in males compared to females. They used a three-dimensional accelerometer to measure trunk flexion-extension in males and females and found that the lumbar contribution to trunk motion was smaller in females than in males. Thus, if older males have decreased spine mobility, this indicates that the difference in results between our study and previous research is reasonable. Furthermore, we suggest that the significant decrease in the sacral inclination angle as our subjects moved from the prone to the puppy to the extension in lying positions was the result of backward tilting of the pelvis to compensate for the inability to perform trunk extension in the puppy and the extension in lying positions.

There was no significant difference in muscle activity between the prone and the puppy positions, indicating that the puppy position does not engage the back muscles. The puppy position has a wide base of support; therefore, there was likely no need to activate the erector spinae and the lumbar multifidus muscles, which are reportedly used for position maintenance[30)], and therefore, the muscle thickness did not change. However, the thickness of the back muscles increased significantly in the extension in lying position compared to that in the prone position. Further, the muscle thickness of the erector spinae muscle and lumbar multifidus muscle at L5 increased significantly in the extension in lying position compared to that in the puppy position. Since the extension in lying position has a narrow base of support, it is suggested that there was a greater need to activate the erector spinae muscle and the lumbar multifidus muscle in this position, which resulted in the muscle thickness change.

There are limitations noted with this study. First, changes in muscle thickness were used to indicate muscle activity based on previous studies which consider increase in muscle thickness to be indicative of muscle activity[18–20]. However, another study reports that the change in the muscle thickness is due to many factors, including the structure of the muscles and the types of muscle contraction and does not only indicate muscle activity[31]. For this study, those considerations are insufficient. In the future, it is necessary to investigate muscle activity using various devices, such as electromyography, muscle hardness testers, and elastography. The second limitation of this study is that the population of participants were healthy older males without low back pain. Hides et al. reports that people with low back pain have atrophy of the back muscles[32]. Therefore, similar measurements may yield different results in subjects with back pain. In order to utilize the three McKenzie positions for the treatment of low back pain in physical therapy, future research targeting subjects with low back pain should be conducted. The third limitation of this study is that we did not examine each lumbar segment. Hides et al. reports that patients with back pain have lumbar multifidus muscle atrophy confined to the lumbar spine segment with symptoms. If muscle atrophy is limited to only the symptomatic segments, the lumbar spine movement may be poor and the mode of muscle activity may change. Therefore, future studies should examine each spinal segment. If continued research addresses the limitations noted in this study, back pain treatments may be further developed.

This study clarified the kinematic characteristics of spinal mobility and muscle activity in older males when performing the prone, puppy, and extension in lying positions used in the McKenzie exercises. While both the puppy and extension in lying positions improved the mobility of the lumbar spine, the puppy position did not change the shape of the back muscles but the extension in lying position did. Hopefully, the findings of this study facilitate future research in the treatment of back pain.

Funding and Conflict of interest

No funding was provided for this study. The author declares no conflict of interest.

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Original Article

Relationship Between Echo Intensity of Healthy Young People and Maximal Anaerobic Power, Endurance

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Abstract. [Purpose] We examined the interrelationship between echo intensity, maximal anaerobic power (Map), and endurance (peak $\dot{V}O_2$) in healthy young men and women. [Subjects and Methods] The 42 young men were aged 19.4 ± 0.8 years and the 29 women were aged 19.6 ± 2.0 years with a mean ± standard deviation. The interrelationship between Map, Peak $\dot{V}O_2$, and the echo intensity of the rectus femoris was analyzed.[Results] In men, there was a significant negative correlation between the echo intensity of the rectus femoris muscle, Map, and peak $\dot{V}O_2$. However, no correlation was observed in women. [Conclusion] It has been reported that an increase in echo intensity has a negative effect on Peak $\dot{V}O_2$ and Map, however the results of this study show that there is a gender difference in the effect of echo intensity on peak $\dot{V}O_2$ and Map. It was suggested that the effects of echo intensity on Peak $\dot{V}O_2$ and Map were not clear in healthy young women.

Key Words: Ultrasound, Echo intensity, Muscle function

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1. INTRODUCTION

Research into the body compositions and muscle functions of men and women suggests that men have high muscle mass and women have high fat mass. It is common knowledge that these differences affect physical performance in daily life and sport. Previous studies have reported that there is a gender difference in muscle mass between men and women, more so in the upper limbs than the lower limbs [1)]. Study [2)] on the difference in muscle power between men and women found that the difference in muscle power between men and women is due to the difference in the muscle fiber cross-sectional area and underlies the difference in skeletal muscle mass. Conversely, studies[3,4)] have reported that women and men with similar performance in terms of whole-body endurance found better whole-body endurance in women than men. Those papers[3,4)] also report that women are characterized by their selective use of fat during whole-body endurance activities. Most measurements of body fat and skeletal muscle mass are measured by dual energy X-ray absorptiometry (DXA), computed tomography (CT), and magnetic resonance imaging (MRI). These devices have both advantages and disadvantages. MRI can measure body detail, however, is very expensive and requires a substantial operational space. DXA and CT that use x-rays are less expensive but more invasive. In recent years, ultrasound devices have attracted attention for evaluating muscle function and research reports on their use have been increasing [5,6,7)]. The advantages of ultrasound are that it is conveniently portable, easy to operate, and unlike the DXA and X-ray methods, noninvasive,

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yet able to quantify the state and dynamics of tissue. In addition, previous studies on echo intensity using ultrasound data have reported that there is a strong correlation between echo intensity (EI) and fat and connective tissue mass after examination by muscle biopsy [8,9]. It is known that if the EI is high, the amount of fat and connective tissue in the muscle is high, and it is said that high EI is affected by muscle weakness [7]. In this study, we investigated the correlation between EI in the rectus femoral, maximal oxygen power (peak $\dot{V}O_2$), and maximal anaerobic power (Map) between healthy young men and women.

2. SUBJECTS AND METHODS

Subjects : 71 Japanese subjects from among the students at the International University of Health and Welfare (42 men, aged 19.2 ± 0.4 years, height 1.72 ± 0.06 m, weight 65.2 ± 6.7 kg, Body Mass Index (BMI)22.0 ± 2.4 kg / m^2 and 29 women aged 19.2 ± 0.4 years, height 1.60 ± 0.05 m, weight 55.3 ± 5.6 kg, BMI 21.7 ± 1.9 kg / m^2 with a mean ± standard deviation). All subjects were informed about the purpose of the research and how the measured data would be used, and their consent was obtained. Exclusion criteria were having a history of respiratory or heart disease, and those whose measurements were not obtained due to physical and mental disorders. This study was conducted in accordance with the Declaration of Helsinki with the approval of the Ethics Committee of the International University of Health and Welfare (approval number:19-Io-190).

Body composition measurements : Body composition was measured using Inbody520 (InBody Japan), a multi-frequency method. First, the sebum was removed from the limb surface with alcohol cotton, and weight was measured according to the user manual. Next, to start the measurement process, height and ID were entered via the input screen and electrodes were placed on the thumb, palm, toe, and heel. After measurement, the weight, BMI, skeletal muscle mass (SMI), body fat percentage (BFP), Fat Free Mass (FFM), and limb skeletal muscle mass (SMM) values were extracted.

Ultrasonographic measurements : For the measurement of EI and muscle thickness(MT), a physiotherapist with 6-years of experience in ultrasonic imaging using a linear probe (>38/ 10-5MHz). A SonoSite 180 Plus ultrasonic diagnostic imaging device in B mode (SonoSite, JAPAN, Tokyo) was used. The ultrasound resolution and gain settings were equal for all subjects. Image depth varied between participants. It has been reported that the degree of image depth does not affect the value of EI [10]. Prior to ultrasonographic measurement, subjects avoided intense exercise and maintained a sitting posture for more than 30 min. Measurements were then performed on the rectus femoris muscle of the dominant leg in the supine position. The rectus femoris measurement site was at a position halfway between the greater trochanter and the knee joint fold. Two top center images were recorded.

Echo intensity analysis : The captured images were transferred to a computer using Sonosite Image Manager (image transfer software), and the data were converted (640 × 480 pixels). The EI of the rectus femoris was measured using ImageJ software (Version 1.52a, National Institutes of Health, USA). The rectus femoris EI quantitative evaluation method was to select as much as possible of the area inside the fascia of the rectus femoris output on the ImageJ screen using the polygon selection function and select it to display from 0 (black) to 255 (white). The evaluation was performed using an 8-bit grayscale that was quantified in 256 steps. The higher the EI value, the higher the proportion of adipose tissue and connective tissue 3,6). MT was measured using the straight selection function to measure the distance between the fascias of the rectus femoris muscles displayed on the ImageJ screen.

Endurance (peak $\dot{V}O_2$) measurements : With subjects wearing a special hooded mask whole-body endurance was measured by the breath-by-breath method using an expired gas analyzer (MINATO, AERO MONITOR 300S) and by gradually ramping a treadmill (BIODEX, GAIT TRAINER) load was applied. For risk management, a physiotherapist licensed for more than 10 years managed any abnormal waveforms and heart rates using an electrocardiogram monitor (NIHON KOHDEN, BSSM-2401). The measurement protocol was as follows: prior to the endurance test subjects were measured in the sitting position for 3 min, the exercise started at 1 km/h, at an incline of 0° and the speed increased by 1 km/h per min from 4 km/h, the 1° incline increased every min. The subjects were instructed to stop if they felt exhausted or unwell, and were informed about using the stop button. The exercise was terminated when the subject completed the exercise task at the maximum speed of 12.8 km/h and the incline was 15°, or when the subject complained. While measuring whole-body endurance, the leveling-off of oxygen uptake ($\dot{V}O_2$) was not confirmed for all subjects, so peak $\dot{V}O_2$ was used for the calculation. Peak $\dot{V}O_2$ was divided by weight. Peak $\dot{V}O_2$ and Maximal anaerobic power (Map) were measured with an interval of at least one week in consideration of fatigue.

Maximal anaerobic power (: Map) measurements : Map was measured using POWER MAX-V3 (KONAMI). The protocol was calculated by repeating the 10 second anaerobic exercise three times in anaerobic power test mode and resting for 2 min between each turn. The value obtained by dividing the Map by weight was calculated. For the Map measurement, a physiotherapist who had been licensed for more than 10 years managed abnormal waveforms and heart rates using an electrocardiogram monitor for risk management.

Statistical analyses : Statistical analysis was performed using IBM SPSS Statistics version 25. Age, height, weight, BMI, BFP, FFM, SMM, EI, MT, peak $\dot{V}O_2$ / weight, and Map/ weight were compared using independent t-tests. Gender separate Pearson's r values were also calculated for these data. The 95% confidence interval (CI) and the significance level of a two-tailed test were calculated for each correlation. The level of significance was 5%.

3. RESULTS

Table1 shows the mean, standard deviations, and ranges for all gender-specific variables, and the independent t-test p-values. There was no significant difference between age and BMI, and significant differences were observed for other items. BFP and EI were significantly higher in women. Height, weight, BFP, FFM, MT, peak $\dot{V}O_2$/weight, Map/weight showed significantly higher values in men.

In men (table 2), EI was significantly correlated with BFP, peak $\dot{V}O_2$/weight, and Map/weight. In women (Table 3), EI did not significantly correlate with other outcomes. There was a significant negative correlation between EI and peak $\dot{V}O_2$ in men ($r=-0.60$, $p=0.01$. 95%CI=-0.99 to 0.37) and no significant difference in women ($r=0.32$, $p=0.09$, 95%CI=-0.04 to 0.73), but a positive correlation was observed. There was a significant negative correlation between EI and Map in men ($r=-0.40$, $p=0.02$, 95% CI=-0.70 to-0.08), and no significant difference was observed in women ($r=-0.14$, $p=0.45$, 95%CI=-0.52 to 0.25), but a negative correlation was found.

4. DISCUSSION

This study aimed to examine how EI in healthy young men and women was related to peak $\dot{V}O_2$ or Map. The results showed that there was a gender difference in the interrelationship between EI, whole Peak $\dot{V}O_2$, and Map. A previous study [1] reported that there was a clear gender difference in SMM. It has been pointed out that differences in muscle strength between men and women are more affected by differences in muscle cross-sectional area than by weight and FFM [11,12]. In other words, it is thought that the difference in SMM influences the gender difference in muscle strength. In this study, it was suggested that there was a gender difference in the performance of Peak $\dot{V}O_2$ and Map and in muscle EI, which represents the "quality" of muscle function.

Comparison of characteristics by gender (Table 1)：There was no significant difference in BMI but BFP and EI were significantly higher in women. The higher BFP and EI in women are common results. The performance of peak $\dot{V}O_2$ and Map was significantly higher in males. A study [11] comparing isometric muscle strength between males and females reported that the muscles in female upper limbs strength were 50-60 % and lower limbs strength 60-80 % where males were 100 %. This is consistent with the results of anaerobic power in this study. Conversely, research reports on whole-body endurance [1,3,4] demonstrate that women perform better in endurance events where exercise is repeated over a long time. Froberg [4] reported that when using a bicycle ergometer to exercise at a load of 80 % and 90 % of maximal oxygen uptake, the 80 % load significantly increased the performance time for women over men. We report that muscle glycogen depletion is slower than that of men, suggesting that women use fat selectively. This suggests that certain endurance activities are better for women than for men. However, in this study, the overall endurance task efficiency was significantly higher in males, but the peak $\dot{V}O_2$ value was considered to be significantly higher in males because of the high additional load on the ramp.

Correlation of peak $\dot{V}O_2$ and Map with EI by gender (table 2,3)：Peak $\dot{V}O_2$ and Map showed significant negative correlations in males. Conversely, no significant correlation was observed in women. This indicates that peak $\dot{V}O_2$ and Map have a negative effect on EI in men, however, it is not clear how EI is affected by peak $\dot{V}O_2$ and Map in women. The correlation between EI and peak $\dot{V}O_2$ in women in Table 3 shows no significant difference but a positive correlational tendency. This suggests that increasing the EI may improve endurance performance. In other words, as reported in previous studies [4], women are reported to perform better in terms of endurance due to their selective use of fat stored in the body. This result supports that study. In addition to the selective use of fat, reports suggest that fat acts on hormones and affects muscle contraction [13]. In other words, it can be inferred that the increase in EI in women is a factor that affects endurance and muscle strength. A study [14] comparing the EI of quadriceps muscles in middle-aged men and women reported that there was no difference between men and women, which is different from the results of this study. In other words, it was found that the gender difference in muscle luminance may differ depending on age.

The limitation of this study is that the number of subjects was small. Therefore, it is necessary to increase the number of subjects in the future. In a study of athletes and women without exercise habits [15], a comparison of endurance in the follicular and luteal phases showed no significant difference between them. In a study of women who have no exercise habits, knee flexion and extension movements were measured and some reports show no difference in muscle strength between menstrual cycles [16]. In this study, women were unable to measure hormonal imbalance or physiological cycle, however, the only limitation therefrom was the absence of an outcome indicating the interrelationship between hormones and the results of this study. In the future, we hope to examine hormone levels. In addition, the endurance task was the gradually increasing load that was high, requiring an adjusted load to be studied. In addition, the EI measurement site in this study was the rectus femoris muscle but the results of examining muscle types I and II may better reflect endurance and Map. I think these should be obtained in the future.

Conclusion：The relationship between EI of quadriceps muscles and muscle strength, muscle endurance was indicated to be different between young men and women.

Funding and Conflict of interest

No funding was provided for this study. The author declares no conflict of interest.

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Table 1 . Characteristics of patients

	Men(n=42)	Women(n=29)	
Age(years)	19.20 ± 0.40 (19.00 — 20.00)	19.20 ± 0.40 (19.00 — 20.00)	
Height(m)	1.72 ± 0.06 (1.61 — 1.88)	1.60 ± 0.05 (1.53 — 1.68)	*
Weight(kg)	65.20 ± 6.70 (53.90 — 80.20)	55.30 ± 5.60 (45.10 — 71.30)	*
BMI(kg/m^2)	22.00 ± 2.40 (18.60 — 28.60)	21.70 ± 1.90 (19.00 — 28.20)	
BFP(％)	16.30 ± 4.90 (6.70 — 29.50)	26.30 ± 3.80 (18.30 — 34.50)	*
FFM (kg)	54.40 ± 4.60 (45.20 — 62.10)	40.60 ± 3.40 (34.00 — 46.70)	*
SMM(kg)	30.70 ± 42.80 (24.90 — 35.40)	22.20 ± 2.10 (18.40 — 25.70)	*
EI	19.60 ± 4.00 (13.70 — 34.70)	26.90 ± 6.40 (17.20 — 42.30)	*
MT(㎝)	2.00 ± 0.30 (1.48 — 2.73)	1.70 ± 0.20 (1.31 — 2.30)	*
Peak VO2 /weight(ml/kg/min)	46.60 ± 7.10 (28.40 — 66.30)	38.10 ± 4.80 (29.70 — 52.80)	*
Map/weight(W/kg)	12.60 ± 1.80 (9.10 — 18.00)	9.50 ± 1.60 (7.10 — 12.40)	*

Mean ± standdard deviation(range). Statistics was independent Student t-test. BMI:body mass index, FFM:Fat free mass, EI:Echo intensity, MT:muscle thickness, BFP:Body fat percentage, SMM:Skeletal Muscle Mss, Map:Maximum anaerobic power, $P<0.05$*.

Table2. correlation between echo intensity and each parameter in men

	EI	MT	BFP	Peak /weight	Map/weight
EI		- 0.30	0.33*	- 0.60**	- 0.40*
MT			- 0.07	0.23	0.41**
BFP				- 0.35*	0.46**
Peak /weight					- 0.24
Map/weight					

Pearson's correlation coefficient r is presented. EI:echo intensity, MT:muscle thickness, BFP:Body fat percentage, Peak:Peak VO_2, Map:Maximum anaerobic power, FFM:fat free mass. SMM:Skeletal Muscle Mass. P<0.05*, P<0.01**

Table3. correlation between echo intensity and each parameter in women

	EI	MT	BFP	Peak /weight	Map/weight
EI		- 0.17	0.01	0.32	- 0.14
MT			0.18	- 0.38*	0.13
BFP				0.00	0.03
Peak /weight					- 0.01
Map/weight					

Pearson's correlation coefficient r is presented. EI:echo intensity. MT:muscle thickness. BFP:Body fat percentage. Peak:Peak VO_2. Map:Maximum anaerobic power. FFM:fat free mass. SMM:Skeletal Muscle Mass. P<0.05*.

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