Comparison of Muscle Activity Based on Ankle Position During Hip Abduction

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Abstract

The hip abductor muscles are considered to be more active if the motion of the distal joint is aligned with that of the proximal joint by ankle joint eversion. However, it is unclear how changes in ankle muscle activity actually affect the muscle activity of the lateral lower extremity muscles. The purpose of this study was to investigate the muscle activity of the lateral lower extremity muscles, including the lumbar muscles, depending on the ankle joint position, and to investigate an efficient activation method of the hip abductor muscles. The subjects were 9 healthy young males. The lower limbs were isolated by hanging the lower limbs with a sling device. The measurement task was to hold the hip abduction position by isometric contraction against the load in the hip adduction direction. The load was applied by a rubber band, and the length of the rubber band was adjusted to produce a loading of 5 kgf. The muscle activity of the gluteus medius, erector spinae, vastus lateralis, and peroneus longus was measured using surface electromyogram. Measurements were taken under three ankle conditions: neutral position, eversion position, and inversion position. The measured data were used to calculate the percent of integrated electromyogram (%IEMG). Statistical analysis included using a repeated-measures analysis of variance with a Bonferroni correction for multiple comparisons. In terms of %IEMG, the erector spinae and peroneus longus during ankle eversion was significantly larger than that in the neutral position. Peroneus longus during ankle inversion was significantly larger than that in the neutral position. However, the %IEMGs of the gluteus medius and vastus lateralis were not significantly different in all ankle positions. In comparison between muscles, the rate of change

of %IEMG (eversion position / neutral position) was significantly larger for ES than for GM and VL. Therefore, it is necessary to set the ankle and spine positions according to the purpose of hip abduction training.

Introduction

The muscles located outside the lower extremity, including the lumbar region, are considered to be involved in the control of motion along the sagittal, horizontal, and frontal planes[1]. Training for muscle strengthening and activation is often required after manual intervention. The hip abductor muscles, such as the gluteus medius (GM), play many roles in controlling the pelvis and the femoral head's deviation within the acetabulum while walking[1)2)], and are often susceptible to muscle weakness in hip diseases such as osteoarthritis[3]. Furthermore, it has been reported that the abductor muscles of the hip joint can also affect the other parts of the body, such as the lumbar and knee joints, due to muscle weakness[4)5)]. Although various methods of hip abductor muscle training have been researched[3)6)7)], the most efficient method to activate the hip abductor muscle has not been established, and many studies are still being carried out. The vastus lateralis (VL) is the only muscle which has its belly located in the middle of the lateral thigh, and has been reported to connect with many tissues, such as the GM, gluteus maximus, and iliotibial band, in addition to the femur and tibia[8)9)]. The patient complained of a contracting sensation mainly from the middle to the distal lateral part of the thigh during abduction, which often results in insufficient activity of the hip abductor muscles. Moreover, pelvic elevation (lumbar lateral flexion) by the erector spinae (ES) is a typical trick motion for training the hip abductor muscles. Excessive pelvic elevation during hip abduction is reported to not only reduce the training effect of hip abduction muscles but also to lead to lumbar disorders[10]. Therefore, when training hip abductor muscles, it is necessary to consider the influence of other muscles as well. Proprioceptive neuromuscular facilitation (PNF) is a known method of activating muscles using movement in other areas[11]. This technique of facilitating muscle activity by using pelvic and ankle joint movements for the hip joint is frequently used; specifically, hip abductor muscles are facilitated through posterior pelvic rotation and ankle joint eversion[12]. It has long been reported that dorsiflexion of the ankle joint during quadriceps training increases the muscle activity of the quadriceps[13]. The hip abductor muscles are also considered to be more active if the motion of the distal joint is aligned with that of the proximal joint by ankle joint eversion, such as in the case of the quadriceps. However, it is unclear how changes in ankle muscle activity actually affect the muscle activity of the lateral lower extremity muscles.

Therefore, the purpose of this study was to investigate the muscle activity of the lateral lower extremity muscles, including the lumbar muscles, depending on the ankle joint position (eversion or inversion), and to investigate an efficient activation method of the hip abductor muscles.

Method

1. Subjects

The subjects were 9 healthy young males without reported pain in activities of daily life; more specifically, the study focused on the dominant legs of the subjects that they would use to kick a ball. Mean (± standard error) age, height, and weight were 26.8±1.3 years, 172.9±1.7 cm, and 70.1±2.3 kg, respectively. None of the subjects had a history of orthopedic problems of the legs or vertebrae.

2. Ethical approval

The study was conducted in accordance with the Declaration of Helsinki. Before the study, we explained its objective and contents to the subjects and informed them that the data obtained would only be used for this study alone, assuring them that the data would be handled with strict confidence to prevent dissemination of personal information. Written informed consent was obtained from all subjects before the study.

3. Measurement positioning and tasks

The subjects underwent measurements in the supine position with the pelvis fixed, and the leg of the measured side was suspended by a sling to reduce the effect of gravity. They were given a task to maintain a position of 30° hip abduction against a load in the direction of hip joint adduction. A rubber band was used to apply this load (Figure. 1); its length was adjusted using a handheld dynamometer (Morby, Sakai Medical, Inc.) to have a force of 5 kgf at a position of 30° hip abduction. Measurements were taken three times each in 1) the neutral position, 2) the

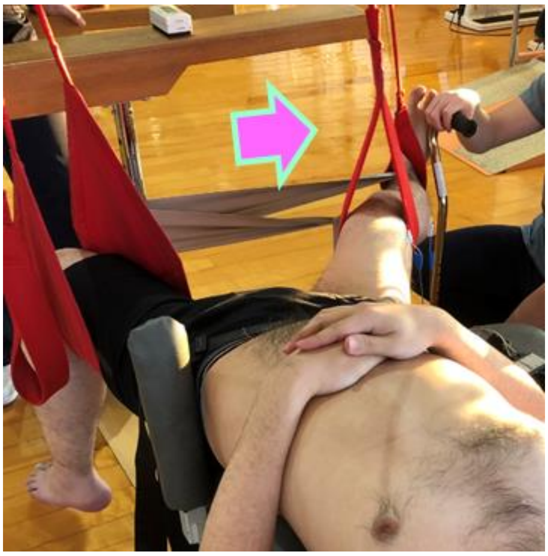

Figure1. Measurement position of EMG measurement.

eversion position, and 3) the inversion position of the ankle joint. The ankle muscles did not contract in the neutral position. Maximum eversion and inversion were maintained by subjects during the corresponding task. Considering the effect of muscle fatigue, sufficient rest time was provided between each measurement task.

4. Electromyography

The muscles measured were the GM, VL, ipsilateral ES, and peroneus longus (PL). Electrode placement was based on Shimono's criteria[14]. The GM electrode was placed 1/3 proximal to the line connecting the greater trochanter and the iliac crest. The VL electrode was placed approximately 3-5 cm proximal to the patella. The PL electrode was placed 1/4 proximal to the line connecting the peroneal head and the lateral malleolus. Lastly, the ES electrode was placed 2-3 cm lateral to the L3 spinous process. Grounding electrodes were placed on the anterior superior iliac spine. Single-use cardiac electrodes (disposable electrode L Vitorode, Nihon Kohden) were used. The distance between the electrodes was 20 mm, and the electrodes were attached parallel to the myofibrillation of each muscle. The skin was treated to keep an impedance range below 10 Kohm. The surface EMG was measured using an EMG system (MQ16 and Viatal Recorder2, KISSEI COMTEC, Inc.). The sampling frequency was set at 1000 Hz, and the activity of each muscle was measured for 5 s with the load. Electromyogram analysis was performed for 3 s, excluding 1 s at the beginning and end of the measurement task, and the integral value (IEMG) was calculated. IEMGs were calculated using a versatile bioinformation analysis program (BIMTAS II, KISSEI COMTEC, Inc.) with bandpass filtering in the range of 10 to 500 Hz and full-wave rectification. Subsequently, the value (%IEMG) relative to that of maximum voluntary contraction was calculated as an index of muscle activity. Maximal voluntary contractions of hip abduction (GM), knee extension (VL), and ankle eversion with plantar flexion (PL) were performed according to the five-level testing of the Danuels' manual muscle test[15]. Lateral flexion of the trunk (ES) was measured in the side-lying position with lateral flexion to the side.

5. Statistical Analysis

SPSS Ver.24 (IBM SPSS Statistics, IBM) was used for statistical analysis. The mean value of the three executions in each position was used as a representative value. After confirming the normality using the Shapiro-Wilk test, repeated analysis of variance and Bonferroni's test were performed to compare the %IEMG for different ankle joint positions in each muscle. The rate of change of %IEMG (eversion position / neutral position and inversion position / neutral position×100) was calculated using one-way analysis of variance and Bonferroni's test. The level of significance was set to 0.05, and all values are presented as the mean ± standard error.

Results

The %IEMGs of each muscle in the different ankle joint positions are shown in Table 1. The %IEMG of ES was significantly larger in the eversion position than for the neutral position, but not significantly different from that of the inversion position. The %IEMG of the PL was significantly larger for the eversion position and inversion position than for the neutral position, but no significant difference was observed between the eversion position and inversion position. The %IEMGs of the GM and VL were not significantly different in all ankle positions. The rates of change of %IEMG for the different ankle positions are shown in Table 2. The rate of change of %IEMG was significantly larger for ES than for GM and VL in the eversion position and neutral position.

Table 1. Comparison of %IEMG for different ankle positions (%).

Ankle position	Eversion position	Neutral position	Inversion position
Gluteus medius	36.0±5.1	35.8±5.4	40.2±6.3
Vastus lateralis	18.8±6.3	20.5±6.0	22.2±6.5
Erector spinae	44.9±7.9*	37.6±6.9	42.1±6.8
Peroneus longus	61.8±16.0*	18.8±6.4	20.1±7.5*

Data are presented as the mean ± standard error.
*: Significant dierences compared to neutral position($p<0.05$).

Table 2. Comparison of The rate of change of %IEMG in different ankle positions (%).

Muscle	Gluteus medius	Vastus lateralis	Erector spinae
Eversion position / Neutral position	101.1±2.8*	90.4±7.8*	126.5±10.9
Inversion position / Neutral position	115.5±13.2	116.8±10.0	118.5±7.1

Data are presented as the mean ± standard error.
*: Significant dierences compared to erector spinae.

Discussion

This study investigated whether lateral lower extremity muscle activity differs depending on the ankle joint positions of eversion and inversion during hip abduction. Clarifying this can help in efficient hip abductor muscle training. The results indicate that the %IEMG of PL is larger in the eversion position than in the neutral position. Therefore, the PL was more active while maintaining eversion, suggesting a difference of ankle muscle activity depending on its position. Moreover, the %IEMG of PL is also larger in the inversion position compared to the neutral position. Mengarelli et al. [16] reported that antagonist muscles are involved in joint stability and motor control by acting in coordination with their agonist muscles. Therefore, %IEMG was larger in the inversion position than in the neutral position because the PL, which is an antagonist muscle, was activated to control its agonist muscle, the tibialis posterior, during inversion. The %IEMG of the ES was larger in the eversion position than for the neutral position, and the rate of change from the eversion position to the neutral position in the ES was larger than that of the GM and VL. Since the muscle activities of the GM and VL do not decrease in the eversion position, it is suggested that the activity of the ipsilateral ES tends to increase rather than changing the ratio of the activity of the lateral lower extremity muscles during the abduction of the same level of hip abduction torque in the eversion position. Therefore, the results of this study are consistent with previous findings[12] that the activity of a proximal muscle is enhanced when the proximal and distal joints move in the same direction. However, from the perspective of hip abductor muscle training, it is not useful for the activation of the hip abductor muscle and might increase load on the lumbar spine. Cynn et al.[17] reported that lumbar stabilization during hip abduction in the side-lying position inhibits lumbar muscle activity and increases GM activity. Therefore, it is considered that hip abduction training using ankle eversion is likely to inhibit ES activity by stabilizing the lumbar spine or by suppressing the pelvis ipsilaterally, and activates the hip abduction muscles located proximal to the lumbar muscles. The influence of neurological mechanisms[18][19] has long been proposed as a mechanism through which differences in ankle muscle activity, which are not directly related to lumbar or hip motion, affect muscle activity in other joints. Moreover, it has been suggested that the myofascial system, which is connected to the muscles and is widely distributed, is involved in force transmission and the activation of specific patterns[20]. However, this study did not examine the changes in muscle activity when the pelvic position was changed or evaluate the mechanism of the changes in muscle activity due to different ankle joint positions; further studies for verification are needed. Limitations of this study include the small number of subjects, and the fact that the pattern of muscle activity due to contraction of ankle joint muscles was not constant and varied greatly. Therefore, it is necessary to increase the number of subjects and classify them according to the patterns of muscle activity in the future. Moreover, the EMG measurements were taken only at representative locations of the hip abductor and lumbar muscles. Therefore, it may be possible to obtain different results by examining each muscle in detail, such as each fiber of the GM, tensor fasciae latae, longissimus, and iliocostalis. It is also necessary to measure the antagonist muscle because of its possible effect, such as the activity of the PL in the inversion position. Lastly, in this study, although we tried to take fatigue-free measurements with sufficient rest time, we did not perform frequency analysis to determine whether the fatigue actually occurred.

Conclusions

During hip abduction, there was no difference in the muscle activity of the GM and VL in different ankle joint positions, but there was greater muscle activity of the ipsilateral ES during eversion compared to the neutral position. Therefore, it is necessary to set the ankle and spine positions according to the purpose of hip abduction training.

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