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Comparison of Electrical Activity Between Vastus Medialis and Vastus Lateralis According to the Difference of Angle of the Femoral Anteversion

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Abstract

The purpose of this research was to analyze the effects of the increase of the femoral anteversion angle on the unbalanced quadriceps femoris muscle causing the increase of the valgus force on the knee joints and patellofemoral pain syndrome by comparing with the group that shows the smaller femoral anteversion angle. The method for the research was to compare the femoral muscle's activity while the subjects were maintaining the knee joint flexed isometrically for 10 seconds. The evaluation tool for femoral muscle's activity was QEMG-4 (model LXM 3204). The results were as followings. Firstly, in case of the experimental group, the muscle strength of the vastus lateralis muscle was strong while the rectus femoris and vastus medialis were weak. In these facts, we can see the statistically meaningful difference in vastus medialis muscle activity. Secondly, in the muscle activity analysis for vastus lateralis and medialis of the two groups, we could see the vastus lateralis muscle was strong in anteversion wider for experimental group while the vastus medialis muscle contracted far more stronger in anteversion smaller for control group. From these results, we can see the significant differences in muscle recruitment between the two groups. Above results show that if the anteversion becomes wider, vastus medialis muscle will become seriously weaker, on the other hand, vastus lateralis act stronger.

Key Words: Anteversion; Isometric exercise; Quadriceps femoris muscle.

Introduction

Recently, as the concerns about the body movements increased, the researches are being actively processed not only about the simple movements aimed at the strengthening, but also about the functional aspects for the efficient body movements. By enhancing muscular strength, the body activities make posture more stable and function to reduce the hazards of the joint injuries and fractures from the muscle fatigues (Snow-Harter, 1994). Especially, compared to the upper body, when lower body moves, because weight-bearing will occur and dynamically considerable load can be taken by joints, abnormal symptoms like pains can be seen in case of even minor problems in body arrangement.

Femoral neck anteversion is defined as the angle between an imaginary transverse line that runs medially to laterally through the knee joint and an imaginary transverse line passing through the center of the femoral head and neck. When the transection passing through the major axis of the femoral neck is vertically united with the diacondylar plane on the axial plane, the solid angle between the two planes will be the anteversion angle, and it is united through to the upper part of the femur (Lee, 1998).

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The increase of anteversion angle triggers the increase of the Q-angle, tibial external rotation, and the pronation of foot, and in the event, patellofemoral pain syndrome can be diagnosed. In this case, the flexibility of the hip flexors, quadriceps femoris, and gastrocnemius must be tested, because these elements have direct and indirect influence upon the placing of the patella on the femur (Choi, 2005).

The contraction of the quadriceps femoris in standing up posture produces the valgus vector on the knee joint (Hungerford and Barry, 1979), and in case of this force is exceeded, it can be the cause of the overuse injuries on the knee joint and adjacent joints, and the symptoms like osteomalacia or relapsing lateral subluxation of the patella can be developed easily. Like this, the femoral anteversion causes the femoral internal rotation by squeezing the femoral head into the acetabulum through the pushing force of the anterior capsulo ligament and frontal muscles. When this happens, because of the internal rotation of the femoral condyle, the changed flexion and extension can make the toe-in gait. By these results, the femoral anteversion can affect the function of the knee joint (Jung et al, 2004) and cause the deformity of the ankle joint.

Because the strength disproportion caused by the deformity of the femoral anteversion triggers the pain on the knee joint, it is needed to take the treatment to reduce the disproportion by strengthening the vastus medialis. For this, it is necessary to selectively practice the exercises focused on the vastus medialis other than the other quadriceps (Blazina et al, 1979; Fisher, 1986; McConnell, 1986), and the exact muscle activity test results for the quadriceps based on the above- mentioned facts will be the greatly important data for the effective selective strengthening exercises. Furthermore, because the more increased the hip flexion, the more increased the couple of forces for the hip joint's medial rotation (Delp et al, 1999), we can expect the couple of forces for the hip joint's medial rotation will be increased when we fulfill the daily movement like going up and down stairs or squatting. The repetition of these daily movements facilitates the patella's lateral subluxation and increases the disproportion of the quadriceps of the patient whose dynamical femoral anteversion angle wider. Therefore, the unbalanced alignment of the lower extremities caused by the nondynamical problem owing to the deformity of the femoral anteversion will affect first on the muscle activity of the quadriceps, and the EMG is very appropriate to objectify these facts.

In related researches, Nyland et al (2004) reported that after having patients practice the exercise under the assumption that the hip joint's anteversion contributes to the joint's medial rotation, the muscle activity of the vastus medialis and gluteus medius had been reduced in the patients whose hip joint anteversion was wider. Alica et al (1992) as well, reported that it was necessary for the patients who had suffered from the knee joint's pain to get rid of the factors that could be the reasons of the functional abnormality of the knee joint and to correct the position of the patella. To do these, they insisted that it was necessary to strengthen the quadriceps and adductors of the hip joint. Like this, actually, the dynamical axis of the lower extremities' weight-bearing passes through the center line of the hip joint, knee joint, and talus, the musculodynamic structure caused by the increase of the hip joint's anteversion in the weight-bearing is so closely associated with the disproportion of the quadriceps. Therefore, in weight-bearing posture, compared to that of the normal subjects, in case of the patients whose anteversion angle is larger, the malposition of the dynamic axis accelerates the disproportion of the quadriceps, and consequently increases the genu valgum of the knee joint and ankle joint's pronation. Herein, the quadriceps' action has the greatest meaning than any other muscles.

The purpose of this research is, by comparing the muscle activities of the quadriceps, to objectively analyze the differences between the two groups that consists of the women who are tending the sick.

They are divided into the larger femoral anteversion group and the smaller. If the femoral anteversion angle is large, the hip joint's internal rotation increases and the larger the angle, the bigger the disproportion of the strength of the quadriceps. The disproportion of the quadriceps can be used to early diagnose the patellofemoral pain syndrome, because it facilitates the valgus force of the knee joint. From these findings, we want to stress the necessity of the selective muscle strengthening for the patients whose anteversion is large.

Methods

Subjects

This research was fulfilled from April 1, 2006 to April 20, 2006 in S-nursing home located in Sungnam City, Kyunggi Do, Korea. The subjects were 30 women from 40~50 years old. Because they were tending the sick, their knee was exposed to the overload from their daily work transferring their patients. We consulted the report that, among the knee joint patients, 18.1% of the man and 33.2% of the women were being suffered from the patellofemoral pain syndrome, and women were more vulnerable (Dehaven, 1986). By considering the average anteversion angle of 19.85±6.90° (Kim and Bin, 1986) for Korean, the subjects were divided into two groups. The experimental group was consisted of 15 women whose hip joint's anteversion angle was bigger than 30° and the control group was consisted of 15 women whose angle was smaller than 20°. We selected the subjects who were qualified for the conditions below.

1) Women who don't have problem in maintaining the standing up balance in blinded condition.
2) Women who don't have LOM in upper & lower extremities and in trunk.
3) Women who don't have problem in ADL, although the knee pain can be accompanied when they move actively.
4) Women who don't have the kinesthetic sense deficit or the decline of the coordination caused by theneurological problem.
5) Women who don't have the muscle weakness or back pain that can influences the gait.
6) Women who don't have the experience of the orthopedic surgery on the hip and knee joint.
7) Women who agreed to participate in the research in person.

Procedures

Measuring instrument

We used the surface EMG[1]. It is the EMG instrument that can measure 4 muscles simultaneously by using 4 channels and the results are displayed on the computer monitor, so the observer can monitor and record. The electrodes were the surface electrodes[2] that were provided for EMG instruments and we attached them on the motor point of muscles (rectus femoris, vastus medialis, vastus lateralis) that act as the knee flexors in isometric exercise. To reduce the skin resistance against the signal, after removing the skin fat with the antiseptic alcohol and spreading the small amount of the electrolyte gel, we attached the surface electrodes on the skin of the thigh and the earthing electrodes on the back.

The way of measuring

We used the Craig test to evaluate the anteversion angle. It measures single tibia's external rotation angle with knee flexed in 90° in prone.

At first, we made the subject straightly stand on both feet on the elastic resistance band. And then we had the subject grip the both ends of the band with the hip joint neutral and knee joint 45° flexed

1) QEMG-4, model LXM 3204, Laxtha, Daejeon, Korea.
2) Ag/Agcl, Laxtha, Daejeon, Korea.

to measure the resistance of the knee extensors in isometric exercise. Herein, the subject was ordered to maintain the posture for 10 seconds while the extra heavy band (blue band) had been pulled to 20 ㎝ to maintain the 1.4 ㎏ of the resistance force of the elastic band. We used a goniometer to measure the knee flexion angle, and ordered to stop after 10 seconds. Because 7 to 10 seconds' resistance is idealistic for the muscle fibers in muscle spindle to arrive to the neurological activity (Chaitow et al, 1996), the subject was contracting the quadriceps for 10 seconds isometrically according to the order of the researcher. During the 10 seconds of the action potential, the 6 seconds' value from 3 to 8 second was taken and we used three times' average value for analysis. The rest time between measurements was 2 minutes, and test was performed randomly, and the total time required was about 30 minutes.

The Measurement for the signal of the MVIC EMG

After removing the markers, to quantify the action potential of the rectus femoris, vastus madialis, and vastus lateralis, we measured each muscle's muscle activity in MVIC (Maximal Voluntary Isometric Contraction). After treating 5 seconds' value with RMS and excluding the first and last 1 seconds, we used the 3 seconds' average EMG signal as the 100% of MVIC.

Statistical Analysis

The independent t-test was fulfilled to compare the two groups' average values for each quadriceps muscle's muscle activity in isometric exercise, and the paired sample test was conducted to checkup the muscle activity of the vastus medialis and lateralis. For the statistical significance level test and statistic process of the data, we used the common statistic programme, SPSS 12.0 for window.

Results

The general characteristics of the subjects

We considered the subjects' age, height, weight, and anteversion angle. The experimental group's average age was 50.88, height was 158.88 ㎝, weight was 57.75 ㎏, and anteversion angle was 41.87°, and the control group's average age was 52.00, height was 157.82 ㎝, weight was 57.45 ㎏, and anteversion angle was 16.36°. Table 1 shows the subjects' general body characteristics.

The comparison of the quadriceps' muscle activity in isometric exercise according to the difference of the femoral anteversion angle

1) The analysis of the muscle activity for rectus femoris muscle

The experimental group's (larger anteversion) muscle activity value for rectus femoris was average 44.40 ㎶, and the control group's (smaller anteversion) was average 49.55 ㎶. From these results, we couldn't find statistically significant differences according to the size of the angle ($p<.05$) (Table 2).

2) The analysis of the muscle activity for vastus medialis muscle

The experimental group's (larger anteversion) muscle activity value for vastus medialis was average 49.38 ㎶, and the control group's (smaller anteversion) was average 62.91 ㎶. From these results, we could find statistically significant differences according to the size of the angle ($p<.05$) (Table 3).

3) The analysis of the muscle activity for vastus lateralis muscle

The experimental group's (larger anteversion) muscle activity value for vastus lateralis was average 58.89 ㎶, and the control group's (smaller anteversion) was average 55.80 ㎶. From these results, we couldn't find statistically significant differences according to the size of the angle ($p<.05$) (Table 4).

Table 1. The general characteristics of the subjects

	Age (yr)	Height (㎝)	Weight (㎏)	Anteversion angle (°)
Experimental group (n=15)	50.88±4.63[a]	158.88±1.16	57.75±5.75	41.87±6.41
Control group (n=15)	52.00±2.75	157.82±4.04	57.45±6.41	16.36±2.86

[a]Mean±SD.

Table 2. The analysis of the muscle activity for rectus femoris muscle

Muscle	Groups	N	Mean±SD	df	t	p
Rectus femoris	Experimental	15	44.40±17.74	28	−.87	.39
	Control	15	49.55±14.69			

Table 3. The analysis of the muscle activity for vastus medialis muscle

Muscle	Groups	N	Mean±SD	df	t	p
Vastus medialis	Experimental	15	49.83±11.45	28	−2.89	.00
	Control	15	62.91±13.29			

Table 4. The analysis of the muscle activity for vastus lateralis muscle

Muscle	Groups	N	Mean±SD	df	t	p
Vastus lateralis	Experimental	15	58.89±15.13	28	.55	.59
	Control	15	55.80±15.42			

Table 5. The comparison of the muscle activity between vastus medialis and lateralis in experimental group

	Difference (Mean±SD)	df	t	p
Vastus lateralis−medialis	9.06±16.22	14	2.16	.04

Table 6. The comparison of the muscle activity between vastus medialis and lateralis in control group

	Difference (Mean±SD)	df	t	p
Vastus lateralis−medialis	−7.11±17.05	14	−1.61	.129

The comparison of the muscle activity between vastus medialis and lateralis according to the difference of femoral anteversion angle

1) The comparison of the muscle activity between vastus medialis and lateralis in experimental group

In experimental group, the average value of the muscle activity in isometric exercise for vastus lateralis was higher than medialis as much as 9.06 ㎶. This is the statistically significant value ($p<.05$) (Table 5).

2) The comparison of the muscle activity between vastus medialis and lateralis in control group

In control group, the average value of the muscle activity in isometric exercise for vastus lateralis was lower than medialis as much as −7.11 ㎶. This isn't the statistically significant value ($p<.05$) (Table 6).

Discussion

The purpose of this research is to analyze the effects of the increase of the femoral anteversion angle on the unbalanced quadriceps femoris muscle by comparing the muscle activities on EMG between the larger anteversion angle group and the smaller.

The measuring methods for the femoral anteversion are largely classified into the fluoroscopic method, the biplanar roentgenography, and the axial roentgenography, and recently the ultrasonic method was reported (Lee, 1989). When evaluate the anteversion in prone position, the patient has to maintain hip joint neutral, and in seating, the patient has to flex the hip joint. We can evaluate the internal & external rotation in prone position, and if the internal rotation is excessive (above 50°) and the external rotation is limited (below 15°), this state can be diagnosed as the anteversion.

In prone position, the Craig test can be accompanied. In this test, while rotating the hip joint internal and externally, a researcher palpates the greater trochanter and determines the range of the greater trochanter's protrusion. In the rotation posture within this range, the femur is ideally located in acetabulum. When measured from the vertical axis and the major axis of the tibia, if the angle is larger than 15° in hip joint's internal rotation, the femur can be diagnosed as the anteversion. With this evaluation, the appraiser can diagnose the femoral anteversion, and this test's reliability is higher than that of the roentgenography. In hip joint flexion position, the contraction of the gluteus maximus can limit the ROM of the internal rotation, but there is no contraction to limit the internal rotation in this test's hip extended and knee flexed position, so the research in this position is reasonable (Kwon et al, 2005).

The correct alignment of the lower body means the ideal alignment state to support the lower body against the load from the upper body, and the neutral position of the pelvis is good for the correct alignment of the lower body (Florence et al, 1993), and consequently prevents the unnecessary energy lose. However, the faulty alignment triggers the unnecessary stress and strain on bones, joints, ligaments, and muscles (Florence, 1993), and the incorrect and repeated movement brings about the deformities of the lower body. The increased faulty alignment of the lower body caused by the muscle unbalance can induce the femoral deformities, and these deformities can be the factor for the forefoot adduction, tibial intorsion, and femoral anteversion (Stulberg, 1980), and the muscle unbalance will be accelerated consequently. Clinically, the hip internal rotation is often accompanied by the femoral anteversion. Furthermore, the congenital dislocation of hip, CP, Legg-Perthes, and in-toeing gait can be accompanied and the excessive anteversion can be the cause of the hip joint's dislocation and subluxation (Kim, 2004). Moreover, the increase of the femoral anteversion is the factor for the increased Q-angle, and because it brings about the abnormal dynamic problems in lower body's weight-bearing, the patellofemoral pain syndrome can be developed (Messier et al, 1991). If the iliotibial tract is tensioned because of the increase of the knee flexion and the reaction force of the patellofemoral joint's plane, the force that pulls the patella laterally increases through the lateral supportive tissues (Choi, 2005).

The excessive femoral anteversion causes the faulty alignment on knee and foot joint, and this alignment triggers the genu valgum on knee and excessive pronation on foot. For instance, in knee flexion, because the contraction force of the quadriceps makes the lateral subluxation of the patella, the vastus medialis must prevent of the subluxation of the patella by pulling it inside (Leveau and Rogers, 1980; Levine et al, 1983; Welsh and Woodall, 1990), but because the vastus medialis is the weakest physiologically, and becomes weak first and recovered last, once it becomes weak, the quadriceps' balance will be broken. Because, like this, the unbalanced quadriceps causes the dynamical change around the knee joint, it will be the factor for the lateral subluxation of the patella (Rouse, 1996). To correctly align the lower body, prevent the abnormal pain, and minimize the secondly deformity, the balance between the vastus medialis and lateralis is very important, because the correct alignment of the knee joint is determined by the muscle balance between these two muscle and the forces of these two muscles affect the Q-angle (Leveau and Rogers, 1980). From these reasons, we can anticipate the fact that the measurement for the Q-angle is important to checkup the muscle balance. Therefore, it is important to checkup the muscle unbalance of the knee joint because the knee joint is in charge of the weight-bearing in standing up posture or in gait. For these reasons, the measurement of the knee joint's Q-angle is clinically important (Woodland and Francis, 1992) and we can anticipate that the disproportion of the quadriceps can facilitate the lateral subluxation of the knee joint.

Leveau et al (1980) said that the excessive femoral anteversion caused the malalignment of the knee and foot joint, and these states caused the knee joint's genu valgum and the foot joint's pronation, and consequently affected the muscles around the joints. In these situation, if the vastus medialis becomes weakened, the balance of the quadriceps will be broken and the broken balance makes the dynamical change around the knee joint, and finally triggers the knee joint's lateral subluxation (Rouse, 1996).

That is, it is critical to predict and prevent the factors like the increase of the femoral anteversion that can cause the patellofemoral pain syndrome in thirties and fifties (Choi, 2005).

Therefore, the comparison of the muscle activity between the larger and smaller anteversion group, and the analysis for the difference between vastus medialis and lateralis are clinically very useful to strengthen muscle selectively. In this research, the larger anteversion group's vastus lateralis was stronger and there were significant differences in the weakness of the vastus medialis. Furthermore, in comparison of the muscle activity between the vastus medialis and lateralis in the larger anteversion group, the vastus medialis was remarkably weak and there was the significant statistic difference.

Werner and Eriksson (1993) reported that the weakness of the knee extensors was the important reason for the patellofemoral pain syndrome. After comparing the EMG values between the knee pain group and the normal group, they found that the agonist and antagonist of the knee extensors were all weakened in the pain group. Generally, the patellofemoral pain syndrome is accompanied by the knee extensors' weakness and atrophy. Na et al (1999) as well, reported that in patellofemoral pain syndrome patients, the vastus medialis contracted later than the lateralis in knee extension, and the extensor's isometric muscle force was significantly increased after 6 weeks' exercise. From this, they found that the kinesitherapy was effective in the strengthening of the quadriceps.

Therefore, from the results of this research, we can know the fact that the increased anteversion angle triggers the muscle disproportion between vastus medialis and lateralis, and the consequent weakness of the vastus medialis is directly related to bring about the patellofemoral pain syndrome. Moreover, because the kinesitherapy can enhance the muscle power of the weakened vastus medialis, the selective muscle strengthening is required to prevent the patellofemoral pain syndrome. Like this, the results are showing that the larger the anteversion angle is, the more the faulty alignment of the lower body is, and if this happen, the balance between vastus medialis and lateralis will be broken, and consequently the increased valgus force on the knee joint causes the patellofemoral pain syndrome.

The limitation of this study is that there were not enough subjects, and there were difficulties in differentiating the congenital and acquired anteversion increase. The more in-depth studies are needed that are focused the people who have the congenital femoral anteversion. With making up for the limitation of this research, we need to further study the pelvis' transversion, gait pattern, and back pain that are related to the increase of the femoral anteversion, and the exercise programme that increases the ROM of the large anteversion patients' hip joint will has to be developed.

Conclusion

In this study, we investigated the 15 larger anteversion group and 15 smaller anteversion group to comparatively study the muscle activity of the quadriceps and the differences between vastus medialis and lateralis according to the different femoral anteversion angle. The results are as below.

First, in case of the experimental group, the muscle strength of the vastus lateralis was strong while the rectus femoris and vastus medialis were weak. In these facts, we could see the statistically meaningful difference in vastus medialis muscle activity.

Secondly, in the muscle activity analysis for vastus lateralis and medialis of the two groups, we could see the vastus lateralis muscle was strong in experimental group while the vastus medialis muscle contracted far more strongly in anteversion smaller control group. From these results, we can see the significant differences in muscle recruitment between the two groups. The statistically meaningful results were found in experimental group but not in the control group.

From the results above, we can know the fact the increased anteversion angle triggers the muscle disproportion between vastus medialis and lateralis, and the consequent weakness of the vastus medialis is directly related to bring about the patellofemoral pain syndrome.

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