

Hip Abduction Muscle Force in Osteoarthritis of the Hip

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In order to clarify the role of the hip abduction force in the occurrence and development of the secondary osteoarthritis (OA) of the hip, isometric hip abduction force and electromyographic (EMG) activities of the muscles around hip were measured simultaneously in 64 hips of 44 female patients. All hips were classified according to radiological criteria of Japanese Orthopedic Association (JOA), and these were 13 hips in the group of preosteoarthritis (pre-OA) stage, 16 hips in early stage, 24 hips in advanced stage and 11 hips in terminal stage. Condition of each hip was evaluated with JOA hip score clinically, with CE angle, and lateral and upward displacement of the femoral head radiologically, and with cross-sectional area of the gluteal muscles in computed tomogram. As control 32 normal hips including opposite side were used.

The maximum abduction force showed no significant difference among the group of control, pre-OA, early, and advanced stage, while significant decrease was noted in terminal stage. In EMG activities of muscle around hip, there was no significant difference among the OA stage group. JOA score and CE angle decreased with the progress of the OA stage. Femoral head showed lateral displacement in the stages up to advanced stage and upward displacement in terminal stage. Gluteus medius muscle had kept its normal cross-sectional area by the advanced stage, and decreased it at the terminal stage.

In conclusion, it was suggested that the occurrence and development of the osteoarthritic changes by the advanced stage in dysplastic hip was not due to the decrease of the hip abduction muscle force.

INTRODUCTION

Most of the osteoarthritis of the hip (OA) in Japan are secondary OA caused by acetabular dysplasia (8). Radiological course of the disease develops from osteosclerosis and narrowing of joint space to osteophyte and cyst formation, while the course is often associated with

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superolateral displacement of femoral head (8,14). It is needless to say that malformations of acetabulum and femoral head are extensively involved in natural course of such pathological conditions (2,6,13,16,18,20,29,31,32,33). However, the modes of pathological progress vary according to individual cases and are not always explicable from radiological findings only (4,21,32). As one of the factors to cause these pathological conditions, attention has been focused on action of muscles around hip joint (5,11,14). Among these muscles, hip abductor is considered as indispensable for the functions of hip joint because hip abductor serves to maintain body balance at coronal plane during one legged standing and to give centripetal force to femoral head (12). Saruwatari (26) determined abductor muscle force before total hip replacement using isokinetic measuring instrument and reported that muscle force of more than 95% of that of young normal subject was maintained in young patients with OA, while muscle force of elderly patients with OA showed about 40% decrease compared with normal subject. Also, Hara (5) describes that abductor muscle force is lower in the patients with OA than in normal subjects, and Kanie (11) reported similar results on limbs affected with OA and normal limbs. Thus, there are reports on the decrease of abductor muscle force in the cases of OA, while there has been no study describing the relationship between stages of OA and muscle force.

The purpose of the present study is to elucidate a role of hip abductor muscle force in the occurrence and development of OA.

MATERIALS AND METHODS

Of 162 cases of secondary OA, which underwent surgical treatment at Department of Orthopedic Surgery, Nagasaki University, over a period from April 1989 to December 1991, 44 cases including 64 hips were selected for the study, exempting the cases with extreme deformation of femoral head or neck and the cases, for which series of muscle force measurements could not be achieved due to pain or contracture. Preoperative radiological stage of OA was classified according to radiological criteria for osteoarthritis of the Japanese Orthopedic Association

(27). There were 13 hips in the group of preosteoarthritis (pre-OA) stage, 16 hips in early stage, 24 hips in advanced stage, and 11 hips in terminal stage, and all patients were female. As control group, 32 hips were selected, which showed no clinical and radiological abnormality, including contralateral hip joints of these patients. Mean age of 4 groups was: 33.2 years in pre-OA stage, 38.4 years in early stage, 38.6 years in advanced stage, 58.3 years in terminal stage, and 37.4 years in control.

Preoperative clinical symptoms were judged according to the criteria of the Japanese Orthopedic Association (JOA score) (27). Also, CE angles and extent of superolateral displacement of femoral head were measured from antero-posterior radiogram of bilateral hip joints, and cross-sectional area of gluteal muscles was measured from the findings on computed tomogram.

For the measurement of abductor muscle force of the hip, isometric hip abductor muscle force measuring system, developed and produced on trial by Murakami (17) and modified by the author, was employed. This system consists of tensile load cell, long leg braces, and trunk fixators. By the tensile load cell, tangential force of an arc drawn by ankle joints during hip joint abduction is measured (Fig.1). Measurement is made at supine position in all cases, and long leg braces are used to maintain both knee joints in extended position. On ankle joint section of the long leg braces, two wheels are provided to reduce friction between the braces and floor surface. The contralateral lower limb is fixed on the measuring system at 15 degrees of abduction (Fig.2), and two trunk fixators are applied on the trunk of the subject to suppress the movement of pelvis and trunk during measurement (Fig.3). The width of the trunk fixators can be adjusted depending upon size of the trunk of the subject so that pelvis and trunk can be firmly fixed.

In synchronization with muscle force measurement during isometric abduction, electromyographic (EMG)

activities of gluteus medius, adductor, rectus femoris and gluteus maximus muscles were delivered by using surface electrodes, which were attached on central region of each muscle belly with 4 cm spacing, and long leg braces and trunk fixators were then mounted. Each subject was instructed to abduct hip joint with maximum efforts for 3 minutes, and muscle force and EMG activities were recorded. The muscle force, i.e. tensile force at ankle joint, was transmitted to the tensile load cell (Kyowa Dengyo; Type LU-50KE) via pulley and was converted to electric signal, which was sent via an amplifier (NEC-Sanei; 6M52) and was recorded on magnetic tape (SONY; SIT-90F) by cassette data recorder (TEAC; MR-30). Surface EMG potential obtained via a multi-purpose telemeter (NEC-Sanei; 511X) was recorded on the tape at the same time with muscle force signal.

Measurement was made on affected limbs and normal limbs at 0 degree of hip joint abduction, 30 degree abduction, 15 degrees abduction, and -15 degrees abduction (15

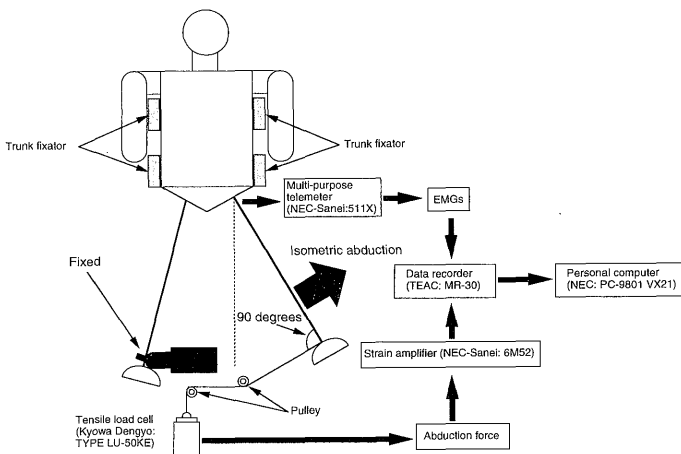


Fig.1 The schematic diagram of measurement system of isometric hip abduction force and electromyographic activities around the hip.

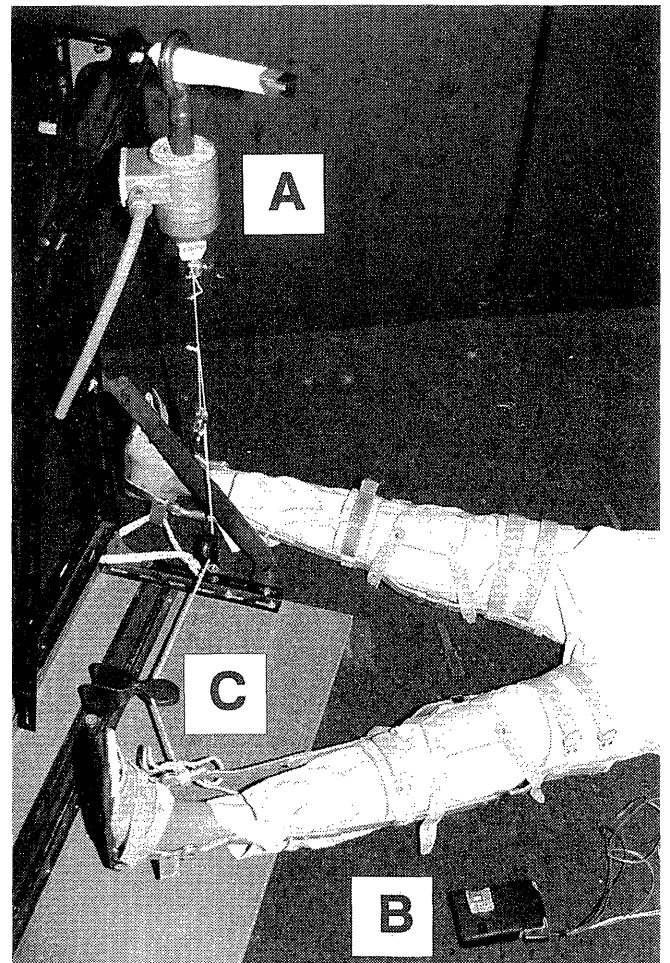


Fig.2 A scene of isometric hip abduction muscle force measurement A: Tensile load cell (Kyowa Dengyo: Type LU-50KE) B: Multi-purpose telemeter (NEC-Sanei: 511X) C: Pulley

Long leg braces were used to maintain both knee joints in extended position.

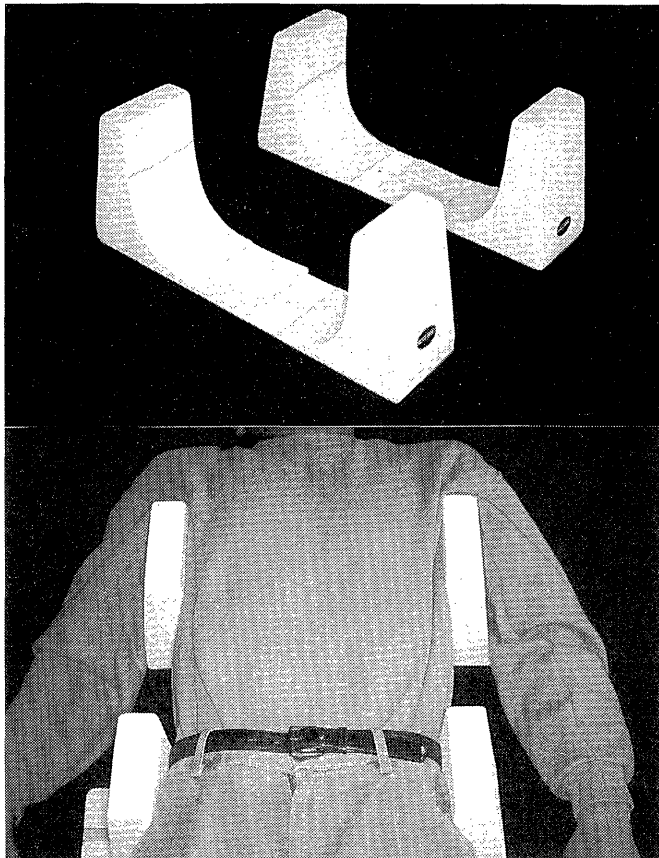


Fig. 3

Top : Trunk fixators

The width of the trunk fixators can be adjusted depending upon size of the trunk of the subject.

Bottom : Application of fixators on trunk of the subject

A pair of trunk fixators were applied on the trunk of the subject to suppress the movement of pelvis and trunk during measurement.

degrees adduction), and rest time of more than 5 minutes was set between the measurements. Measurements of muscle force and EMG activities at each abduction angle could be achieved in almost all cases of pre-OA and early stage groups and control group. In advanced and terminal stage group, muscle force could not be measured at 15 degrees and 30 degrees abduction position because the range of motion was limited in 3 and 10 hips respectively. The data recorded on magnetic tape was analyzed by computer (NEC; PC-9801VX21) using computer software (Hip Joint Abduction Evaluation System; H ABDUS)

developed by the co-worker Dr. Chiba.

Based on the above results, comparative study was performed for each stage on ① JOA score and radiological measurement values, ② maximum abduction muscle force and durability of abductor muscle, ③ relationship between EMG activities and abduction muscle force, and ④ cross-sectional area of gluteus medius, gluteus maximus and gluteus minimus muscle.

RESULTS

(1) JOA scores for each stage

The scores for pain were: 32.3 ± 8.9 in pre-OA stage group, 23.8 ± 7.8 in early stage group, 18.9 ± 9.3 in advanced stage group, and 14.5 ± 9.9 in terminal stage group, and significant difference was noted between control group and pre-OA stage and between pre-OA stage and early stage, but there was no significant difference between early stage and advanced stage and between advanced stage and terminal stage. In the range of motion, significant difference was noted between early stage and advanced stage and between advanced stage and terminal stage. In walking ability, significant difference was found between advanced stage and terminal stage. In ADL, significant difference was noted between early stage and advanced stage and between advanced stage and terminal stage (Table 1).

(2) CE angles for each stage

In CE angles, there was significant difference between control group and pre-OA stage group, and between pre-OA stage group and early stage group (Fig. 4).

(3) Abduction muscle force and durability of hip abductor for each stage

Isometric muscle force under maximum efforts showed maximum value immediately after starting of measurement and gradually decreased with fluctuations (Fig. 5). First, it was examined whether attenuation of abduction muscle force approximates primary attenuation curve of $Y = A \cdot e^{-kt}$ (e: exponential function, t: time) or not. The coefficient of correlation between isometric hip abduction force and primary attenuation curve was calculated for each stage of OA. As a result, mean values of coefficient were relatively high, being 0.827 to 0.933 at four abduction limb positions (Table 2). These results indicate that it is reasonable to approximate the attenuation of abduction

Table 1 JOA scores for each stage

Stage	Pain (40points)	Range of motion (20points)	Walking ability (20points)	ADL (20points)
Pre	32.3 ± 8.9	19.8 ± 0.5	16.9 ± 4.6	19.0 ± 2.3
Early	23.8 ± 7.8	19.0 ± 1.4	13.1 ± 5.0	18.8 ± 1.6
Advanced	18.9 ± 9.3	17.3 ± 2.2	11.9 ± 4.3	16.1 ± 3.1
Terminal	14.5 ± 9.9	15.7 ± 1.4	7.3 ± 3.3	10.6 ± 3.3

(* : $P < 0.05$)

force to the attenuation curve of $Y=A \cdot e^{-kt}$ (Fig. 5). In this equation, if the time t is infinitely approximated to 0, $A \cdot e^{-kt}$ is turned to A , and this is the maximum value (kgW) of abduction muscle force. Also, if t is $1/k$, A is turned to $A \cdot 1/e$. Since muscle force is attenuated by $1/e$ for each $1/k$ second, $1/k$ (time constant) expresses durability of the muscle. Accordingly, maximum muscle force and durability were calculated.

a) Maximum muscle force

Mean value of maximum muscle force of hip abductor showed the highest value in control group, being -15 degrees abduction. With the increase of abduction angle to 0, 15, and 30 degrees, muscle force decreased, and significant difference was noted among these three abduction positions ($p<0.01$). Similar difference was noted in the groups of pre-OA stage, early stage, advanced stage and terminal stage group. In the hip abduction of -15, 0 and 15 degrees, there was no significant difference in maximum muscle force in control, pre-OA stage, early stage and

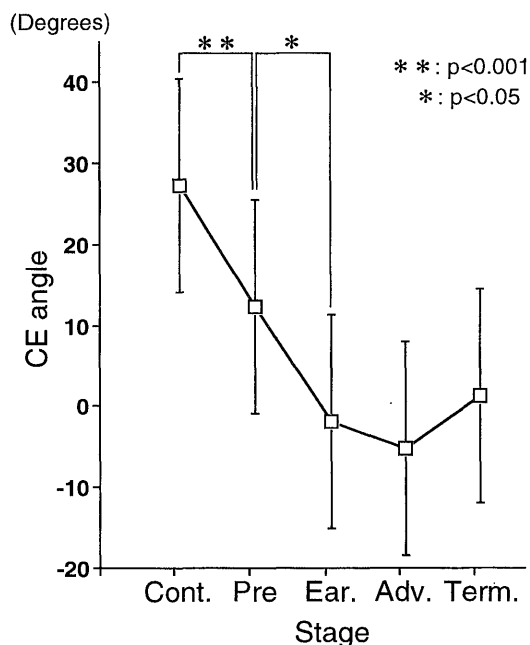


Fig. 4 CE angles for each stage

CE angle showed significant decrease between control group and pre-OA group between pre-OA group and early stage group. (Cont.: control group, Pre: pre-OA stage group, Ear.: early stage group, Adv.: advanced stage group, Term.: terminal stage group)

advanced stage group, while significant decrease was found in the terminal stage group ($p<0.05$). In 30 degrees abduction, there was no significant difference among control group, pre-OA stage, early stage and advanced stage group (Fig. 6).

b) Durability of hip abductor

Mean value of durability of hip abductor exhibited the highest value in abduction of -15 degrees in all stages. In pre-OA stage, early stage, and advanced stage group, durability at -15 degrees abduction showed significantly higher value compared with the values of 0, 15 and 30 degrees abduction ($p<0.05$). However, no significant

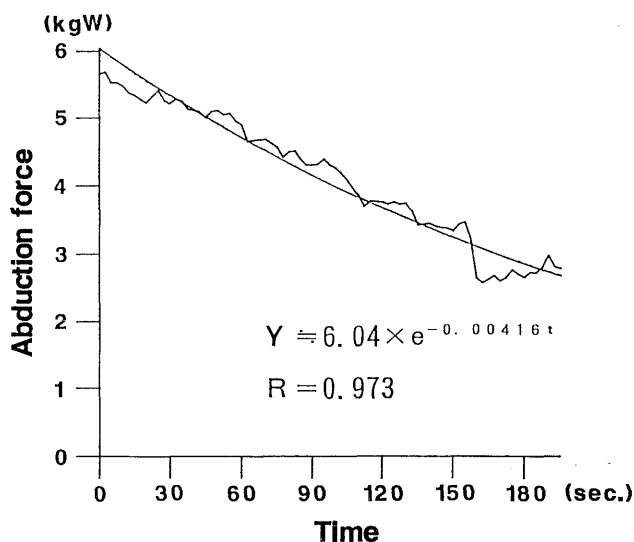


Fig. 5 An example of the alteration of the isometric hip abduction muscle force of 41-years old female at 0 degree abduction position and the approximation curve to the exponential function.

Isometric muscle force under maximum efforts showed maximum value immediately after starting of measurement and gradually decreased with fluctuations. There is an exponential relationship between the hip abduction force, Y , and time, t ; Y decreases exponentially as t increases (as the equation shown below). The exponential decrease depends on the value of the parameter k , and the value of $1/k$ (time constant) expresses durability of the muscle, and A expresses the maximum value (kgW) of abduction muscle force. For example, the maximum abduction force was estimated as 6.04 kgW (A) and the durability was calculated as 240 seconds ($1/0.000416$) in this case with a correlation coefficient of 0.973 (R).
Equation: $Y(t) = A \times e^{-kt}$ (e = exponential, t = time)

Table 2 The coefficient of correlation between isometric hip abduction force and primary attenuation curve at four abduction position

Stage	Limb position (degrees)			
	Abduction -15	Abduction 0	Abduction 15	Abduction 30
Contro	10.902±0.090	0.932±0.051	0.855±0.109	0.827±0.133
Pre-	0.933±0.075	0.911±0.072	0.900±0.067	0.836±0.158
Early	0.844±0.088	0.912±0.113	0.892±0.074	0.854±0.097
Advanced	0.916±0.082	0.900±0.109	0.909±0.069	0.879±0.095
Terminal	0.889±0.128	0.907±0.072	0.847±0.105	-

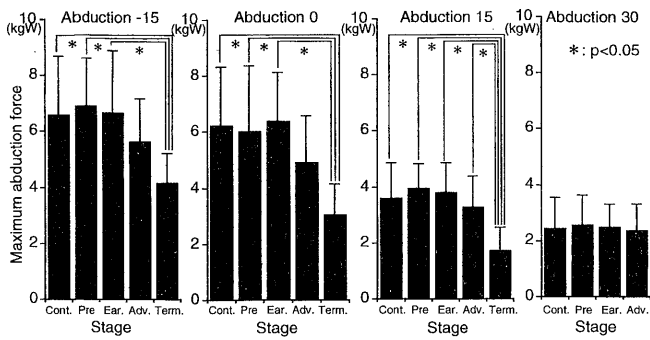


Fig. 6 Maximum muscle force of hip abductor for each stage at four different positions

In the hip abduction of -15, 0 and 15 degrees, there was no significant decrease in maximum muscle force in control, pre-OA stage early stage and advanced stage group, while significant decrease was found in the terminal stage group. In 30 degrees abduction position, there was no significant difference among control group, pre-OA stage, early stage and advanced stage group. (Cont.: control group, Pre: pre-OA stage group, Ear.: early stage group, Adv.: advanced stage group, Term.: terminal stage group)

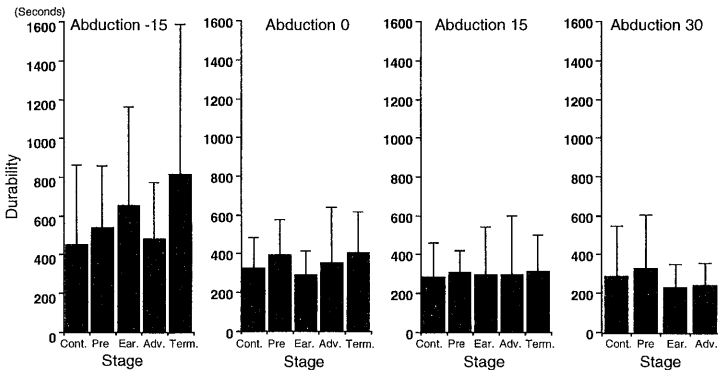


Fig. 7 Durability of hip abductor for each stage

No significant difference was recognized due to difference of stages. (Cont.: control group, Pre: pre-OA stage group, Ear.: early stage group, Adv.: advanced stage group, Term.: terminal stage group)

difference was recognized due to difference of stages (Fig. 7).

(4) Relationship between abduction muscle force and EMG activities of muscle around hip for each stage

In order to clarify the relationship between abduction muscle force and EMG activities of the muscles around hip during isometric hip joint abduction, regression coefficient and correlation coefficient of two variables of abduction muscle force value and integrated EMG value were calculated by the methods as described below. First, EMG potential was rectified by a self-made digital rectifier, and the results were integrated for each time series, regarding 3 minutes of measurement time as one unit (about 72 units in the present study) (Fig. 8). Further, simple regression analysis of each integrated EMG value and the corresponding abduction muscle force values was performed to calculate regression coefficient and correlation coefficient

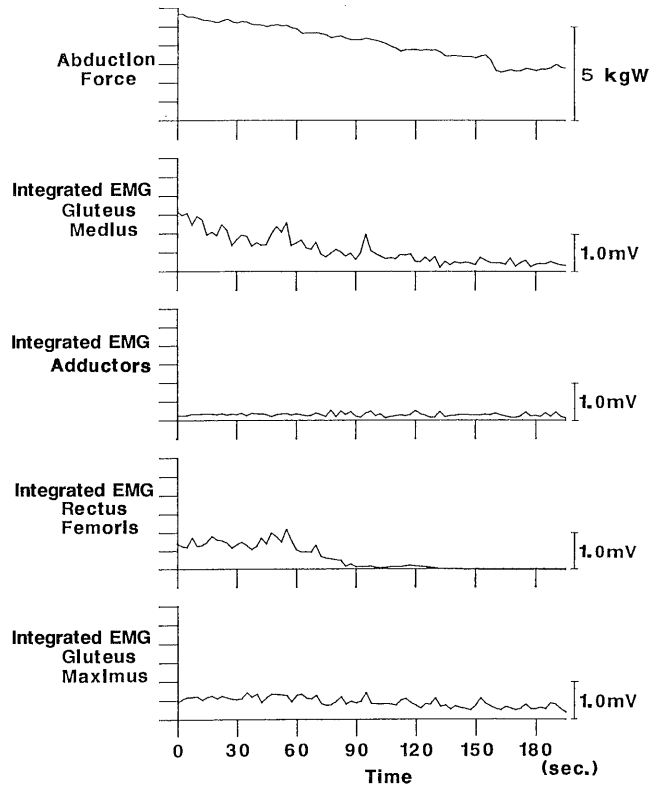


Fig.8 Hip abduction force and integrated EMGs of muscles around hip joint

The alteration of the hip abduction force is shown on the top, and integrated EMGs of the gluteus medius, adductors, rectus femoris and gluteus maximus are shown from the second row to the bottom. The curve of the integrated EMG obtained from gluteus medius muscle relatively resembles to the curve of the hip abduction force.

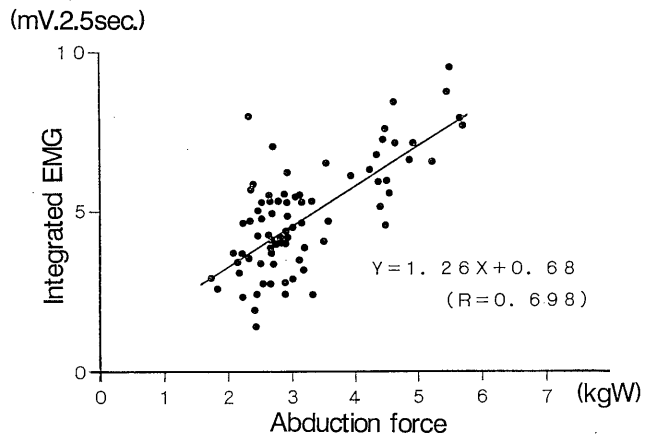


Fig. 9 An example of scatter diagram of hip abduction muscle force and integrated EMG of gluteus medius during abducting hip under maximum efforts at 0 degree abduction position

Simple regression analysis was carried out between abduction muscle force value and each of these four integrated EMGs of gluteus medius, adductors, rectus femoris and gluteus maximus. The regression coefficient and correlation coefficient were 1.26 and 0.698 respectively in this case.

Table 3 The regression coefficient between isometric hip abduction force and integrated EMGs at 0 degree abduction position

Stage	Gluteus medius	Adductors	Rectus femoris	Gluteus maximus
Control	0.306±0.189	0.021±0.031	0.407±0.263	0.146±0.170
Pre-	0.388±0.230	0.019±0.053	0.266±0.207	0.280±0.207
Early	0.442±0.235	0.000±0.051	0.213±0.158	0.192±0.186
Advanced	0.282±0.121	0.029±0.043	0.241±0.195	0.109±0.105
Terminal	0.226±0.162	0.023±0.034	0.283±0.207	0.214±0.160

Table 4 The correlation coefficient between isometric hip abduction force and integrated EMGs at 0 degree abduction position

Stage	Gluteus medius	Adductors	Rectus femoris	Gluteus maximus
Control	0.664±0.229	0.241±0.314	0.618±0.328	0.561±0.233
Pre-	0.718±0.143	0.154±0.296	0.588±0.225	0.560±0.223
Early	0.778±0.134	0.061±0.344	0.627±0.331	0.577±0.263
Advanced	0.708±0.176	0.184±0.325	0.596±0.268	0.507±0.260
Terminal	0.616±0.145	0.125±0.295	0.554±0.337	0.539±0.175

(Fig. 9). The regression coefficient shows inclination of linear regression line and indicates the degree of the EMG potential of the muscle around hip at the time of hip abduction. The correlation coefficient shows reliability of the regression coefficient.

The regression coefficient of abduction muscle force and integrated EMG value of 4 muscles around hip joint at 0 degree abduction position was calculated for each stage. These values were 0.226 - 0.442 in gluteus medius, 0.000 - 0.029 in adductor, 0.213 - 0.283 in rectus femoris, and 0.109 - 0.280 in gluteus maximus (Table 3). Correlation coefficient was: 0.616 - 0.778 in gluteus medius, 0.061 - 0.184 in adductor, 0.554 - 0.627 in rectus femoris and 0.507 - 0.577 in gluteus maximus (Table 4). No significant difference was noted between stages in regression coefficient and correlation coefficient of abductor muscle force and EMG. Similar trend was observed at the other three abduction positions.

(5) Superolateral displacement of femoral head for each stage

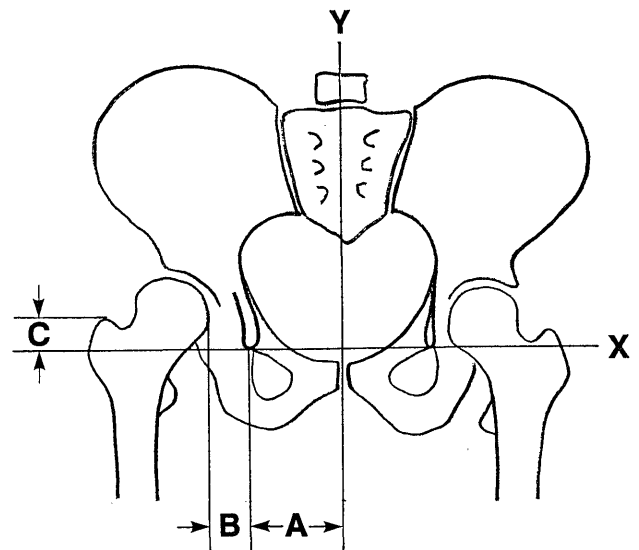
Because the center of femoral head is often difficult to determine in the measurement of superolateral displacement of femoral head, the following method was employed: First, on antero-posterior radiogram of bilateral hip joints taken with pubic symphysis at the center, a straight line X connecting lower ends of bilateral tear drops and a straight line Y passing the center of pubic symphysis and perpendicular to the straight line X was drawn. It is supposed that the distance between intersection of the straight lines X and Y and lower end of tear drop is A, the distance between medial end of femoral head and lower end of tear drop is B, and the distance between the straight line X and apex of greater trochanter is C. The value $B/A \cdot 100$ was considered as lateral displacement index (LDI), and $C/A \cdot 100$ was regarded as upward displacement index (UDI) (Fig. 10).

In LDI, significant difference was noted between control and early stage group and between pre-OA stage and

advanced stage group. In UDI, there was significant difference between pre-OA stage and advanced stage group and between early stage and terminal stage group (Fig. 11). There was no difference between control and pre-OA stage group or early stage group.

(6) Relationship between superolateral displacement of femoral head and maximum abduction muscle force

The relationship between LDI and maximum abduction muscle force at each abduction position was evaluated in 64 hip joints. As a result, there was no significant correlation between LDI of femoral head and maximum abduction

**Fig. 10** The measurement method of the displacement of the femoral head.

A: Distance between intersection of the straight lines X and Y and lower end of tear drop

B: Distance between medial end of femoral head and lower end of tear drop

C: Distance between the straight line X and apex of greater trochanter

Lateral displacement index (LDI) = $B/A \times 100$

Upward displacement index (UDI) = $C/A \times 100$

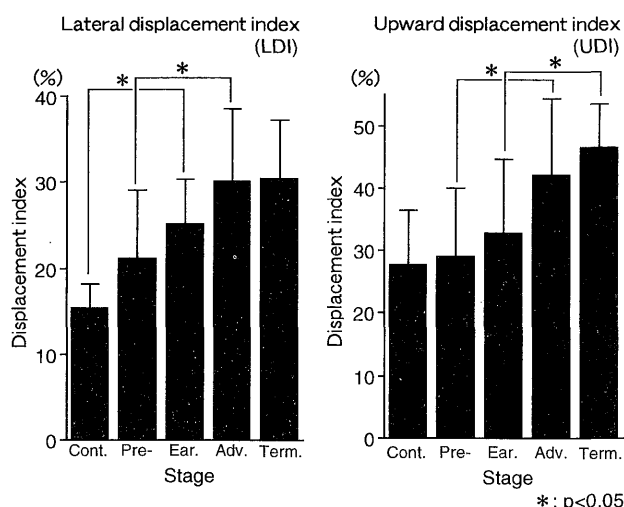


Fig. 11 Displacement indices of femoral head for each stage. In lateral displacement index (LDI), significant difference was noted between control and early stage group and between pre-OA stage and advanced stage group. In upward displacement index (UDI), there was significant difference between pre-OA stage and advanced stage group and between early stage and terminal stage group. (Cont.: control group, Pre-: pre-OA stage group, Ear.: early stage group, Adv.: advanced stage group, Term.: terminal stage group)

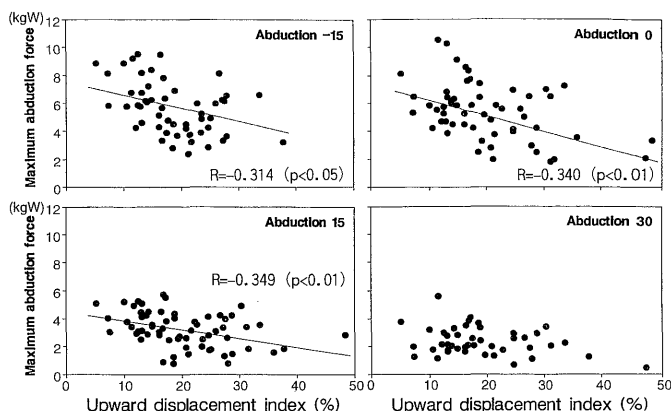


Fig. 13 The scatter diagrams of the UDI and maximum abduction muscle force at four different abduction position. Significant correlation was noted between UDI and maximum abduction muscle force at -15 degrees, 0 degree and 15 degree abduction position.

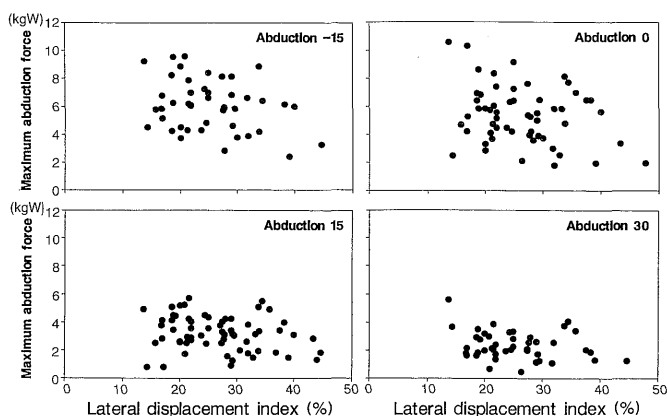


Fig. 12 The scatter diagrams of the LDI and maximum abduction muscle force at four different abduction position. There were no significant correlation between LDI and maximum abduction muscle force in any position.

muscle force (Fig. 12). On the other hand, significant correlation was noted between UDI and maximum abduction muscle force at -15 degrees abduction, 0 degree abduction and 15 degrees abduction position (Fig. 13).

(7) Cross-sectional area of gluteal muscles for each stage

For the measurement of cross-sectional area of gluteal muscles, computed tomogram at the level of lower edge in iliosacral joint was used. Contours of gluteus minimus, gluteus medius and gluteus maximus muscle were inputted in computer using a digitizer (GRAPHTEC; KD9060), and actual cross-sectional area was calculated using graphic measurement software (GRAPHTEC; MEAS1) and

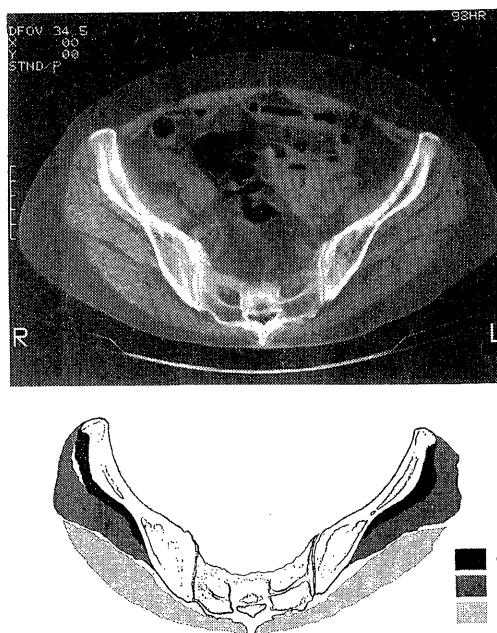


Fig. 14 An example of the computed tomogram and its schema of the gluteal muscles.

The tomogram was taken at the level of the lower edge in iliosacral joints, and cross-sectional area of gluteus minimus, gluteus medius and gluteus maximus muscle were measured by computer aided digitizer.

converting the reduced scale (Fig. 14).

In cross-sectional area of gluteus minimus, no significant difference was noted between control and each of the OA stage groups. In cross-sectional area of gluteus medius, significant difference was found between control and terminal stage group, and pre-OA stage and terminal stage group ($p < 0.05$). In cross-sectional area of gluteus maximus, significant difference was also noted between terminal stage group and each of control, pre-OA stage and early stage group ($p < 0.05$) (Fig. 15).

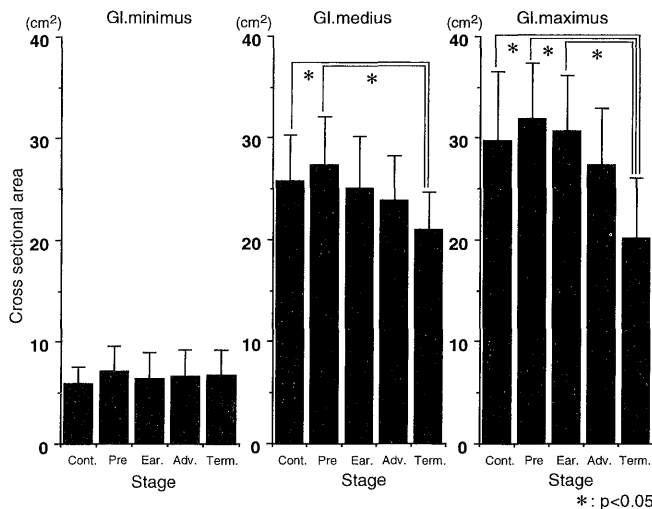


Fig. 15 Cross-sectional areas of gluteal muscles for each stage

In cross-sectional area of gluteus minimus, no significant difference was noted control and each of the OA stage groups. In cross-sectional area of gluteus medius, significant difference was found between control and terminal stage group, and pre-OA stage and terminal stage group. In cross-sectional area of gluteus maximus, significant difference was noted between terminal stage group and each of control, pre-OA stage and early stage group.

DISCUSSION

To ensure sufficient and effective function of muscles, muscles must have sufficient strength and endurance. To measure muscle force, there are three testing methods: isotonic testing, dynamic isokinetic testing and isometric testing. Of these, isometric testing cannot measure workload, but the reliability of measured value is high because there is no joint movement during measurement. Also, it is useful to measure even in case of OA with pain and motion disturbance.

Murakami (17) measured hip abduction force on normal healthy male subjects using a simple cable tensiometer system consisting of rope and load cell and demonstrated that attenuation of isometric muscle force for 3 minutes under maximum efforts can be approximated by exponential function of $Y = A \cdot e^{-kt}$. The results of the present study reveals that the attenuation of isometric abduction muscle force can be approximated to exponential function $Y = A \cdot e^{-kt}$ in the case of OA. To identify dynamic characteristics of hip abductors, maximum muscle force and durability were calculated for each abduction position and for each stage using the exponential function, and it was evaluated how these values change as OA progresses. As a result, no significant decrease in maximum muscle force was noted in any of the measured abduction position even when stage progressed from pre-OA stage to early stage and further to advanced stage. Only in the terminal stage, it was

found that the values significantly decreased. On the other hand, durability of abductor was at the longest at -15 degrees abduction, being 475 to 811 seconds. However, there was no significant difference in the durability between stages.

Further, the relationship between muscle force during isometric hip abduction at supine position and EMG activity of muscle around hip was evaluated by calculating regression coefficient and correlation coefficient for each stage. As a result, regression coefficient to gluteus medius was at the highest, and next followed that of rectus femoris muscle, gluteus maximus muscles and adductor muscles, and it was apparent that gluteus medius played an important role in abduction of hip joint. According to Kapandji (12), gluteus maximus is involved in abductors as a muscular unit called "deltoid of the hip" together with tensor fasciae latae muscle. Murakami (17) recognized the EMG activities of rectus femoris muscle during abduction and considered it as stabilizer at the time of hip abduction, while Lanz (15) identifies this as one of abductors. However, in these EMG activities, no significant change was noted between OA stages.

As described above, in dynamic characteristics of abductor, there was no apparent difference in the stages from pre-OA to advanced stages. However, clinical symptoms positively aggravated as stage progresses. From radiological viewpoint, CE angles showed extreme decrease from pre-OA to early stage and this change agrees with the increase of lateral displacement of femoral head. In the advanced stage to the terminal stage when upward displacement of femoral head occurs, there is no decrease of CE angles. Such radiological findings are reflected in abductor muscle force, and no decrease of muscle force occurs during the stage when CE angles decrease or lateral displacement of femoral head increases, whereas muscle force decreases in the stages when upward displacement increases.

Tajiri (26) measured cross-sectional area of muscles around hip for each stage and reported that significant atrophy of gluteus maximus and gluteus medius was noted in pre-OA, early and advanced stages, and atrophy of gluteus minimus was added to this in the terminal stage. In contrast, Itoh (12) describes that, in gluteus medius in the case showing high greater trochanter, compensative hypertrophy was found in pre-OA stage, and atrophy and lipotrophy were noted in early and advanced stages. The results of the present study reveal that mean value of cross-sectional areas of gluteus medius and gluteus maximus were at the highest in pre-OA stage and significantly decreased in terminal stage compared with control, pre-OA stage and early stage group. In gluteus minimus, there was no difference in all stage groups. These results do not always agree with the findings of Tajiri et al. but concur well with the changes of maximum muscle force of abductor. These facts suggest that hip abductor force does

not play an important role in the developmental process from early stage to advanced stage of OA. Bombelli (3) describes that, of the resultant force R passing through the center of femoral head, horizontal component force Q is directed inwardly in normal hip joint, while it disappears in hip with acetabular dysplasia. In case of extreme acetabular dysplasia, it works as a component force S directed toward superolateral direction, following subluxation of its femoral head. However, there is no definite description as to which muscle is responsible for this process. In a study using rigid spring model, Ohashi (23, 24) reported that higher abduction muscle force is needed to prevent superolateral displacement of femoral head in acetabular dysplasia. In his study, only body weight and abduction muscle force are evaluated, and question arises as to how the actions of the other muscles are. Hirohashi (7) performed reinforcement training of gluteus, iliopsoas muscle, quadriceps and hamstring muscles for OA patients, and reported that pain resolved clinically in more than 90% of the cases in pre-OA and early stages and in about 70% of the cases in advanced stage. Doesn't this suggest that reinforcement of other muscles rather than abductor muscle force was effective in the cases of pre-OA and early stages of OA? Nakajima (19), Aoki (1) and Kageyama (10) performed kinetic therapy of muscle around hip in advanced and terminal stages and reported improvement of clinical symptoms. In the present study, abductor muscle force apparently decreased in advanced and terminal stages, and this may indicate significance of the reinforcement of abductor muscle. Further, Aoki reported that kinetic therapy was not effective to the cases of OA in pre-OA and early stages, and this may support the results of the present study.

The above results suggest that lateral displacement of femoral head first occurs in hip joint having acetabular dysplasia, whereas this is not caused by weakenings of hip abductor muscle force. In addition to malformation of hip joint and load, muscle force around hip other than abductor muscle force may be related to this. Lateral displacement of femoral head increases resultant force of hip joint, and the lateral region of the weight bearing area in acetabulum is destroyed and deformed due to stress and this may cause upward displacement of femoral head. Such deformation and destruction of hip joint further enhances pain and weakens abductor muscle force together with upward displacement of femoral head. With these factors being causes and results, instability of hip joint is aggravated and may result in pathological condition of terminal OA.

CONCLUSION

1) In order to elucidate the role of hip abductor muscle

force on occurrence and development of secondary OA, isometric hip abductor muscle force and EMG potential of muscle around hip were measured on 64 joints of preoperative cases of osteoarthritis (13 hips in pre-OA stage, 16 hips in early stage, 24 hips in advanced stage, and 11 hips in terminal stage), and the results were compared for each stage. Also, the pathological conditions were evaluated clinically using JOA scores, and CE angle and lateral and upward displacement of femoral head radiologically, and further using cross-sectional area of gluteal muscles in computed tomogram. As control, 32 joints including those on normal side were used.

- 2) In maximum muscle force, there was no significant difference among the groups of control, pre-OA, early, and advanced stages, while significant decrease was noted in terminal stage. In EMG activities of muscle around hip, there was no significant difference for each stage. JOA scores and CE angles decreased with the development of stages. Femoral head showed lateral displacement in the stages up to advanced stage and upward displacement in terminal stage.
- 3) These results suggest that, in hip joint having acetabular dysplasia, occurrence of OA and development up to subsequent advanced stage are not caused by decrease of abductor muscle force.

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