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Does Fracture Severity of Intertrochanteric Fracture in Elderly Caused by Low-Energy Trauma Affected by Gluteus Muscle Volume?

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Purpose: The aim of this study was to determine whether there is a correlation between the type and stability of intertrochanteric fractures caused by low-energy trauma and gluteus muscle volume.
Materials and Methods: A total of 205 elderly (>65 years) patients with intertrochanteric fractures caused by low-energy trauma treated from January 2018 to December 2020 were included in this study. The mean age of patients was 81.24 years (range, 65-100 years). Fractures were classified according to the Jensen modification of the Evans classification. The cross-sectional area of the contralateral gluteus muscle (minimus, medius, and maximus) was measured in preoperative axial computed tomography slices. An analysis and comparison of age, body mass index (BMI), weight, height, and the gluteus muscle area in each fracture type group was performed.
Results: In the uni-variable analysis, statistically significant taller height was observed in patients in the stable intertrochanteric fracture (modified Evans 1 and 2) group compared with those in the unstable intertrochanteric fracture (modified Evans 3, 4, and 5) group (P<0.05). In addition, significantly higher BMI-adjusted gluteus muscle area (gluteus muscle area/BMI) was observed for the stable intertrochanteric fracture group compared with the unstable intertrochanteric fracture group except for the BMI-adjusted gluteus minimus area (P=0.112). In multivariable analysis, only the BMI-adjusted gluteus maximus (P=0.042) and total gluteus areas (P=0.035) were significantly higher in the stable group.
Conclusion: Gluteal muscularity around the hip, especially the gluteus maximus, had a significant effect on the stability of intertrochanteric fractures.

Key Words: Intertrochanteric fractures, Buttocks, Hip fracture, Body mass index

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INTRODUCTION

An increase in the older population has resulted in a drastic increase in occurrence of intertrochanteric fractures in elderly persons[1]. Fractures around the hip including intertrochanteric fractures are associated with a high degree of morbidity, mortality, and disability. Even with aggressive operative treatment, the 1-year mortality rate may be high, at over 25%[2]. Significant factors in the success of internal fixation of intertrochanteric fractures include the fracture pattern, as well as the implant position, patient compliance, and the severity of osteoporosis[3-6].

Several studies have been conducted and are some are underway to determine the correlation between the incidence of hip fractures and bone mineral density (BMD); results of these studies have shown that patient BMD around the hip showed a significant correlation with the incidence of intertrochanteric fractures[7,8]. However, the factors affecting the stability of intertrochanteric fractures in low-energy injuries (simple falls) have not been definitely determined[9].

We hypothesized that muscularity around the hip affects the pattern of intertrochanteric fractures. Body mass index (BMI) was used to correct for the muscle volume (area) in each patient's physique. BMI was calculated using weight divided by height squared, representing the cross-sectional mass of a certain person. Therefore, we assumed that the BMI-adjusted gluteus muscle area represented muscularity around the hip.

MATERIALS AND METHODS

1. Patient Selection

A total of 276 consecutive patients over 65 years of age with intertrochanteric fractures treated at the authors' orthopedic department from January 2018 to December 2020 were initially selected. The exclusion criteria were previous contralateral hip injury or spinal fracture, the inability to walk before the injury, bone tumors, spinal cord injury, cerebrovascular disease, and congenital or neuromuscular disease that can affect muscle power and high-energy injury. A total of 205 patients were finally included. A description of the excluded cases is shown in Table 1.

Table 1. Summary of Excluded Cases

	No. of cases
Total	276
Included	205
Excluded	71*
Exclusion criteria	
Cerebrovascular disease causing hemiparesis (cerebral infarction, hemorrhage)	23
High energy injury	21
Previous contralateral hip injury	15
Inability to walk before injury	11
Severe spinal stenosis causing muscle weakness or previous spinal cord injury	7
Fracture due to bone tumor	3
Congenital abnormality on hip	2
Neuromuscular disease	2

* Sum of excluded case is 84 but excluded cases were 71, because several patients meet multiple exclusion criterias.

2. Data Collection and Analysis

The initial assessments including radiographic measurements (X-ray and whole pelvic bone computed tomography [CT] including the contralateral hip) were performed in order to evaluate the type of fracture and for planning operative procedures. An external investigator who did not participate in the surgical procedures performed an analysis of the patient's sex, age, BMI, and preoperative function. For all 205 patients, the radiographic evaluations were performed within a week after trauma. On the plain X-ray, each patient's fracture was classified by three investigators (B.K.K., S.H.J., and D.H.H.) according to the Jensen modification of the Evans classification[10].

In addition, the area of the gluteus minimus and medius at the S3 level, the gluteus maximus at the greater trochanteric tip level of the contralateral hip were measured three times by three investigators on the axial cut on pelvic CT with the Marosis M-view using a free draw area measuring utility tool (Fig. 1).

Because muscle and soft tissue swelling in the injured hip can exaggerate the gluteus muscle area we checked the area of the contralateral hip muscle and we excluded conditions that can cause severe asymmetry in hip muscle volume. Patients with intertrochanteric fractures were divided into the stable fracture (Evans 1 and 2) and unstable fracture (Evans 3-5) groups. Patient age, sex, BMI, weight, height, and each gluteus muscle area (minimus, medius, and maximus) and sum, and BMI-adjusted (muscle area/BMI) gluteus muscle areas were compared.

Statistical analyses were performed using IBM SPSS Statistics for Windows (ver. 25.0; IBM, Armonk, NY, USA); statistical significance was set at $P<0.05$. Sample size was estimation for effect size (d=0.5) and power ($1-\beta=0.95$) was 204. The intraobserver and interobserver correlation coefficient for area of gluteus minimus were 0.89 (95% confidence interval [CI], 0.86-0.92) and 0.82 (95% CI, 0.79-0.85). The intraobserver and interobserver correlation coefficient for area of gluteus medius were 0.92 (95% CI, 0.89-0.94) and 0.88 (95% CI, 0.85-0.91). The intraobserver and interobserver correlation coefficient for area of gluteus maximus were 0.87 (95% CI, 0.84-0.90) and 0.85 (95% CI, 0.82-0.89).

This study was approved by the Institutional Review

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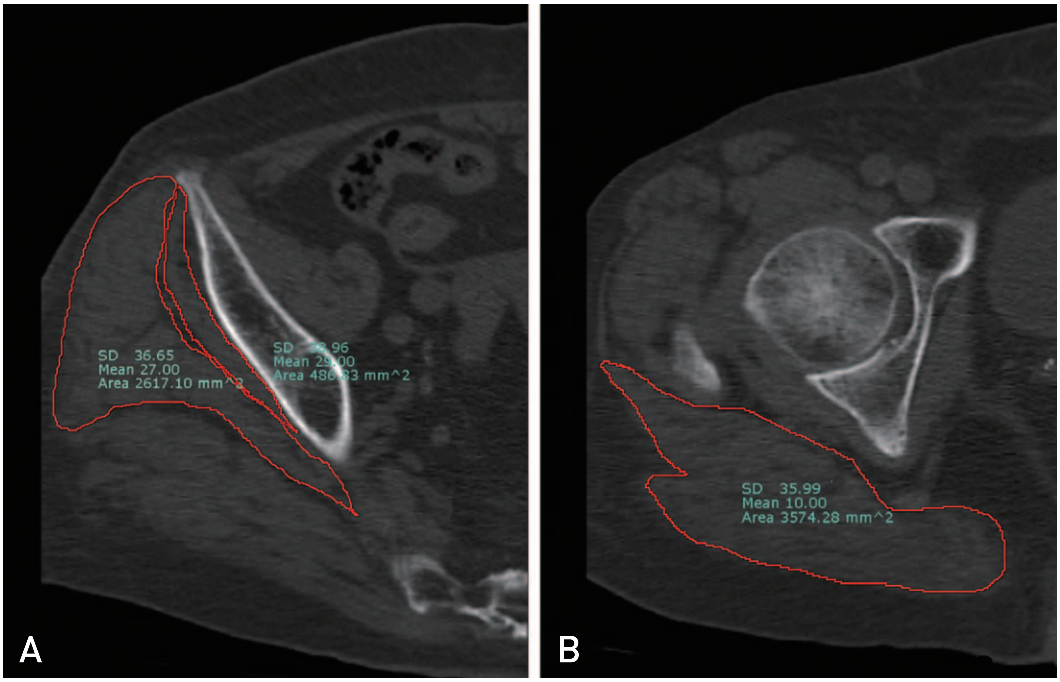

Fig. 1. Cross sectional area measurement on axial computed tomography cut. (A) Gluteus minimus and medius area measurement on S3 level. (B) Gluteus maximus area measurement on greater trochanter tip level.

Board (IRB) of CHA Gumi Medical Center (No. GM21-11), and the informed consent was waived by the IRB.

RESULTS

The mean age of patients was 81.24 years (range, 65-100 years). The male-to-female ratio was 48:157. Details regarding age, height, weight, BMI, and the muscle area (gluteus minimus, medius, and maximus) parameters of each Evans fracture group are shown in Table 2. The stable fracture group (Evans 1 and 2) and the unstable fracture group (Evans 3-5) were also analyzed (Table 3).

1. Uni-Variable Analysis

As shown in Table 3, age, weight, and the BMI parameters in both groups were not statistically different ($P>0.05$) but sex ($P=0.025$) and height were statistically different ($P=0.011$). The gluteus minimus, medius, and maximus were slightly larger in the stable fracture group than in the unstable group but the differences were not statistically significant. However, the BMI-adjusted gluteus medius ($P=0.025$), maximus ($P=0.009$), and total area ($P=0.006$) were significantly larger in the stable group with statistical significance.

2. Multi-Variable Analysis

ANCOVA (analysis of covariance) was performed in order to adjust the effect of age, sex, and height on other variables. A higher BMI-adjusted gluteus maximus area ($P=0.042$) and BMI-adjusted total gluteus area ($P=0.035$) were observed for the stable fracture group compared with the unstable group, which were statistically significant.

In uni-variable analysis, a difference in height was observed between the two groups but not in the multivariable analysis because the stable group included more males and males were taller than females in this study. Similarly, the males in this study also showed larger gluteal muscle cross-sectional areas. As demonstrated by the results of the multivariable study, after adjusting for covariates such as sex and age, only the difference in BMI-adjusted maximus and total gluteus area between the two groups was statistically significant.

DISCUSSION

When an elderly person falls and a fracture occurs, several factors can be considered in determining the fracture pattern. Bone strength, forces applied to the body, and protective factors can be considered[9].

Healthy bones have endurance and can be maintained in

Table 2. Comparison between Modified Evans Fracture Groups

	Evans 1	Evans 2	Evans 3	Evans 4	Evans 5	Total
No. of cases	18	45	66	30	46	205
Sex (M:F)	10:8	11:34	12:54	3:27	12:34	48:157
Age (yr)	73.83±6.19	83.13±6.71	81.32±7.14	82.57±7.99	81.30±7.47	81.24±7.58
Height (cm)	165.22±7.88	156.89±7.23	155.33±7.80	155.60±6.15	157.43±8.08	157.19±7.99
Weight (kg)	60.36±9.21	53.21±11.62	52.11±11.27	51.41±9.66	54.67±8.64	53.67±10.68
BMI (kg/m^2)	22.04±2.41	21.45±3.36	21.49±3.65	21.22±3.74	22.05±2.97	21.61±3.38
Gmini (mm^2)	501.17±162.22	476.27±170.77	457.34±152.04	459.66±137.54	434.42±146.69	448.54±154.85
Gmed (mm^2)	2,011.17±498.13	2,058.89±548.58	2,010.36±478.27	1,827.96±418.03	1,874.88±379.54	1,977.58±476.17
Gmax (mm^2)	2,710.11±671.59	2,516.31±648.74	2,454.10±683.57	2,390.43±570.64	2,336.60±541.06	2,438.07±637.23
Gtotal (mm^2)	5,222.44±1,227.08	5,051.47±1,265.12	4,921.80±1,164.69	4,678.05±945.10	4,645.90±913.72	4,864.19±1,128.67

Values are presented as number only or mean±standard deviation.
Gmini: gluteus minimus cross-sectional muscle area, Gmed: gluteus medius cross-sectional muscle area, Gmax: gluteus maximus cross-sectional muscle area, Gtotal: Gmini+Gmed+Gmax.
M: male, F: female, BMI: body mass index.

low-energy injury. However, osteoporosis in elderly patients is common and these patients experience various fractures[7,8,11,12]. BMD measurements are regarded as a tool for measurement of bone strength and stratifying the risk of fracture. Kim et al.[13] suggested that BMD scores were higher in the control group than in the hip fracture group, and higher BMD scores were observed for the stable intertrochanteric fracture group compared with the unstable intertrochanteric fracture group. It is undebatable whether BMD is an intuitive tool for assessment of bone quantity and represents bone strength indirectly (or directly). However, there is still controversy with regard to whether there is an association between improving BMD by bisphosphates or other osteoporosis drugs with a greater decrease in fracture risk[14-17].

When a fracture occurs, the force applied to the body can be affected by several factors. Many studies have been conducted to investigate the mechanism of low-energy hip fractures in elderly patients; a sideways fall is the most common cause of falls that result in hip fractures. In this study, we included simple height-level falls. However, the force that caused the fracture varied according to the patient's position at the moment of injury, the direction of the fall, weight, height, and the patient's protective response in "just" a simple height-level fall[18-21]. de Bakker et al.[22] suggested that impacting the greater trochanter to ground was the cause of hip fractures to either the femoral neck or intertrochanter. Some studies supported the finding that the direction of impact could have an effect on some aspects of intertrochanteric fractures. The findings of these studies suggested that an impact on the posterolateral side of the hip could cause maximum injury to the intertrochanteric area[23,24]. This was supported by findings from several finite element model studies; however, conduct of prospective studies on the effect of the direction of the impact on hip fractures is impossible.

Lower extremity length is dependent upon body height, assuming people have similar body proportions. When an elderly person falls, taller people may experience greater impact[18,25] which can, consequently, result in a more unstable fracture. However, according to Opotowsky et al.[25], body height is not always an accurately indication of lower extremity length and taller body height can lower BMI and impact force. In our study, results of uni-variable analysis showed that patients with taller height tended to have more stable intertrochanteric fractures; however, it was not relevant in multivariable analysis. As described in the results, this outcome was due to the higher proportion of males in the sta-

Table 3. Comparison between Stable Fracture Group and Unstable Fracture Group

	Stable (n=63) Evans 1, 2	Unstable (n=142) Evans 3-5	*P*-value	*P*-value (ANCOVA)
Sex (M:F)	21:42	27:115	0.025*	
Age (yr)	80.48±7.86	81.58±7.48	0.339	
Weight (kg)	55.2±11.53	52.79±10.26	0.130	0.617
Height (cm)	159.27±8.39	156.07±7.67	0.011*	0.130
BMI (kg/m²)	21.66±3.15	21.65±3.49	0.999	0.740
Gmini (mm²)	483.38±168.85	450.4±148.29	0.161	0.426
Gmed (mm²)	2,045.25±539.38	1,927.94±444.38	0.105	0.193
Gmax (mm²)	2,571.68±666.49	2,402.58±621.45	0.080	0.130
Gtotal (mm²)	5,100.32±1,266.84	4,780.93±1,055.87	0.062	0.106
BMI-Gmini	22.73±7.61	21.03±6.78	0.112	0.369
BMI-Gmed	96.56±23.01	89.77±18.31	0.025*	0.086
BMI-Gmax	121.55±31.02	111.21±23.10	0.009*	0.042*
BMI-Gtotal	240.84±55.48	222.01±38.97	0.006*	0.035*

Values are presented as number only or mean±standard deviation.
Gmini: gluteus minimus cross-sectional muscle area, Gmed: gluteus medius cross-sectional muscle area, Gmax: gluteus maximus cross-sectional muscle area, Gtotal: Gmini+Gmed+Gmax, BMI-Gmini: Gmini/BMI, BMI-Gmed: Gmed/BMI, BMI-Gmax: Gmax/BMI, BMI-Gtotal: Gtotal/BMI.
M: male, F: female, BMI: body mass index.
* $P<0.05$.

ble group than the unstable group, who were taller than the females in this study.

Force distribution to the bone can be altered by protective factors such as subcutaneous fat and muscles. However, fat and muscles have weight, thus it can be assumed that these factors concomitantly have positive and negative effects on the forces to the bone when a patient falls[18,19]. When an elderly person with a higher body weight falls, the generated impact force is greater than that of a slim person. In contrast, a person with a higher weight may have a thick soft tissue like subcutaneous fat layer and gluteus muscles over the greater trochanter so that they have better protection[18,19]. According to a study by Bouxsein et al.[18], BMI was a strong predictor of hip fracture risk, and the risk of fracture was significantly increased with a low BMI. These results can be interpreted in two ways. Many studies have reported the positive effects of BMI on BMD[26,27] and persons with higher BMIs tend to have higher BMDs, which directly or indirectly affects bone strength[27]. From another perspective, this implies that protection of soft tissue is more important than the impact force generated by mass. In our study, differences in the BMI-adjusted gluteus maximus and total gluteal volumes were observed between the two groups. One reason for the differences could be that the muscle contracts at the moment of impact, distributing the force to the surrounding tissues and bones, absorbing shock more effectively than subcutaneous fat. However, conduct of additional finite element model studies is required. Clinically, the impact force and impact velocity on the greater trochanter in elderly patients with intertrochanteric fractures during sideways falls cannot be measured directly or prospectively. However, in biomechanical studies with cadavers[18,28], the energy absorbed during the fall and impact was a more important component than bone strength in hip fractures. Previous studies employed a three-dimensional finite element model to simulate falls. Protection of soft tissue is believed to be helpful in lowering the incidence of fracture. Many more studies support the former reason than the latter; however, both interpretations are possible.

In this study, BMI was used to adjust the muscle volume (area) in each patient's physique. BMI is an indirect measure of body fat based on height and weight that applies to adult men and women. BMI was calculated using a person's weight in kilograms divided by the square of height in meters. However, there are many weaknesses in using BMI as a measure of obesity. The BMI represents the cross-sectional mass of a certain person. We assumed that the value derived from dividing the gluteal muscle area by the BMI could indirectly represent each person's gluteal muscularity. However, from another perspective, the area value (mm^2) divided by the BMI (kg/m^2) is meaningless; this value is generated for statistical reasons. However, no exact value can represent a person's muscularity; therefore, we used BMI-adjusted gluteal muscle area to represent hip muscularity.

The limitations of the current study were as follows. (1) No BMD or impact direction was evaluated. This was a retrospective study. The BMD of approximately 20% of the enrolled patients was evaluated, which provided insufficient data for analysis. In addition, checking the direction of impact in the medical record was clinically difficult and inaccurate. (2) In this study muscle quality and function were not evaluated and the proportion of fatty degeneration in gluteal muscles was not measured. Use of software like the National Institutes of Health (NIH) ImageJ (NIH, Bethesda, MD, USA) software program could be a solution. Furthermore, only one cross-sectional area of each muscle may not accurately represent the volume of each muscle. (3) Other muscles around the hip were not analyzed. (4) The dominant leg was not checked. Muscle volume and strength can differ according to leg dominancy[29].

CONCLUSION

Gluteal muscularity around the hip, especially the gluteus maximus, had a significant effect on the stability of intertrochanteric fractures.

CONFLICT OF INTEREST

The authors declare that there is no potential conflict of interest relevant to this article.

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