

Correlation between preoperative body composition and postoperative muscle volume and degeneration after total hip arthroplasty

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Research Article

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Abstract

Background: Impaired muscle recovery after total hip arthroplasty (THA) may greatly affect gait and activities of daily living. Bioelectrical impedance analysis (BIA) may be used to assess body composition and muscle volume and computed tomography (CT) may be used for assessing muscle volume and, using Hounsfield units, fatty degeneration of muscle. This study aimed to assess the correlation between preoperative body composition and postoperative muscle volume and degeneration after THA using BIA and CT.

Methods: Thirty-seven patients who underwent THA and had BIA and CT performed both pre- and postoperatively were retrospectively assessed. Body composition measurements, specifically the fat mass index, fat-free mass index, and phase angle, were recorded using BIA. Pre- and postoperative muscle volume and Hounsfield units of the gluteus maximus and quadriceps of the affected hip were measured using CT. The correlation between preoperative body composition measurements and postoperative muscle volume and Hounsfield units of the gluteus maximus and quadriceps was evaluated.

Results: Preoperative fat mass index negatively correlated with postoperative muscle volume of the gluteus maximus ($P=0.02$) and quadriceps ($P<0.001$) and the Hounsfield units of the gluteus maximus ($P=0.03$) and quadriceps ($P=0.03$). Preoperative fat-free mass index positively correlated with postoperative muscle volume of the quadriceps ($P=0.02$). Preoperative phase angle positively correlated with postoperative muscle volume of the quadriceps ($P=0.001$) and the Hounsfield units of the gluteus maximus ($P=0.03$) and quadriceps ($P=0.001$).

Conclusion: In patients who underwent THA, preoperative body composition correlated with postoperative muscle volume and fatty degeneration of the affected lower limb. Preoperative body composition may be useful for predicting postoperative muscle volume and fatty degeneration and thus the extent of postoperative recovery.

Background

As population aging has progressed, the number of total hip arthroplasties (THAs) has been increasing. Globally, the number of THAs is expected to increase by 174% from 2005 to 2030 [1]. THA reduces hip pain and increases quality of life [2]. Although THA enables patients who suffer from hip pain to regain an almost normal gait balance [2, 3], this balance is affected by the strength of individual muscles of the hip [4, 5]. Muscle mass, strength, and physical function are greatly variable among individuals [6]. Although this may be affected by some factors such as sex, heredity, and the intrauterine environment, the remaining variables have not been fully elucidated [6].

Computer tomography (CT) is used for evaluation of both the muscle volume and muscle degeneration using Hounsfield units (HUs) [7–10]. Body tissue can be distinguished based on densities, such as fat (-100 HU), water (0 HU), muscle (30–50 HU), and bone (400–1000 HU) [11]. Therefore, fatty degeneration

of muscle after THA may be assessed using HU and CT [12, 13]. Although CT is helpful for evaluating muscle volume and fatty degeneration, radiation exposure is a concern and less invasive devices that can assess muscle volume and adipose degeneration would be preferable. Body composition parameters, such as bone mineral content and body fat, have recently gained attention, because they may be associated with the physical function [14]. Therefore, a simple and non-invasive apparatus would be helpful to assess body composition. Bioelectrical impedance analysis (BIA) is widely used for assessing clinical condition [15] and obesity [16]. BIA can be used to individually assess the fat mass index (FMI) and fat-free mass index (FFMI), simply and non-invasively, by using a harmless electrical current [17, 18]. Additionally, BIA is widely used to assess segmental skeletal muscle mass [19, 20]. Skeletal muscle volume directly affects sarcopenia and decreasing muscle strength may cause a limping gait after THA. Thus, accurate assessment of skeletal muscle is important. BIA can also assess the phase angle (PhA), which represents the angle between electrical impedance and cell membrane resistance [21]. PhA is also known to be associated with cellular health, body cell mass, integrity of the cell membrane [21–23], muscle mass [24], body fat [25], and malnutrition [26, 27], in addition to aiding in muscle quality improvement [28], muscle strength [29], and functional status [30, 31].

Although preoperative body composition can affect muscle volume and degeneration after THA, to the best of our knowledge there are no current studies that elucidate the correlation between preoperative body composition and muscle volume and adipose degeneration after THA. The purpose of this study was to determine if preoperative body composition (FMI, FFMI, PhA) correlated with muscle volume and/or muscle adipose degeneration after THA.

Methods

Patient enrollment

This study retrospectively investigated 38 patients who underwent THA between 2018 and 2021. Demographic data is shown in Table 1. All procedures were approved by the Institutional Review Board of the University of Tokai (21R-311). Participants had BIA performed one month before and CT six months after THA. Inclusion criteria were as follows: (1) patients who underwent BIA and CT pre- and post-THA; (2) patients who could walk without a walker before THA. The exclusion criteria were as follows: (1) patients who used a wheelchair before THA and (2) patients who had undergone ipsilateral surgery around the hip.

Table 1
Demographic data

| Characteristic | Patients (n = 38) |
|---|-------------------|
| Age (years) | 61.6 ± 16 |
| Sex (male:female) | 15:20 |
| BMI (kg/m ²) | 23.8 ± 5.8 |
| Diagnosis (OA:ION:RA:RDC) | 18:17:2:1 |
| Preoperative leg discrepancy (mm) | -9.5 ± 8.2 |
| Postoperative leg discrepancy (mm) | -3.2 ± 8.8 |
| Preoperative offset (mm) | 41 ± 6.4 |
| Postoperative offset (mm) | 40 ± 6.4 |
| BMI: Body mass index, OA: Osteoarthritis, ION: Idiopathic osteonecrosis of the femoral head, RA: Rheumatoid arthritis, RDC: Rapidly destructive arthropathy | |
| All values are expressed as mean ± standard deviation | |

Surgical procedure

All patients underwent THA using the anterolateral supine (ALS) approach. The same acetabular components (Continuum; Zimmer Biomet, Warsaw, IN, USA) and femoral components (Fitmore; Zimmer Biomet, Winterthur, Switzerland) were placed in all patients. Full weight-bearing was allowed from the day after the surgery.

Body composition measurements

Anthropometric measurement

Height was measured to the nearest 0.1cm using a fixed stadiometer. Weight was measured using a digital scale (seca, Hamburg, Germany) to the nearest 0.1kg in the standing position. Body mass index (BMI) was calculated as body weight (kg) divided by height, squared (m²).

Bioelectrical impedance analysis

Body composition (FMI, FFMI, and PhA) was measured using multi-frequency bioelectrical impedance analysis (mBCA515; seca, Hamburg, Germany, Fig. 1). This device can also separately measure impedance in the limbs at 19 frequencies ranging from 1 kHz to 1,000 kHz. FMI, FFMI, and PhA was calculated from the manufacturer's proprietary software. Participants had body composition measured once in the standing position, with four electrodes at the feet and four electrodes at the hands. Participants were instructed to remain standing position during the scan for 17 seconds.

CT evaluation

CT was performed from the range of the anterior superior iliac spine (ASIS) to the knee joint (Siemens, Germany; 120 kV, slice thickness; 0.6 mm, 0.5–1 s scan time). The anterior pelvic plane (APP) was defined using landmarks of the bilateral ASIS plane and pubic tubercles [9]. The cross-sectional area (CSA) of the affected gluteus maximus was measured at the most proximal point of the affected greater trochanter. The CSA of the affected quadriceps were measured at the middle of the affected thigh. Considering each participant's physique, the measured muscle volume was normalized for each patient's body weight (mm^2/kg). Each muscle was measured by manual tracing and HU was measured using imaging analysis software DICOM in a 512×512 pixel format (Fig. 2). Two observers separately measured each muscle twice and the average value was used for evaluation.

Statistical analyses

The Wilcoxon signed-rank test was used for evaluating pre- and postoperative FMI, FFMI, PhA, muscle volume and HU of the gluteus maximus and quadriceps. Spearman's rank correlation test was performed to assess correlation of preoperative FMI, FFMI, and PhA and postoperative muscle volume and HU. All tests were performed at a significance level of $P < 0.05$. Analyses were performed using the SPSS statistical software version 26 (IBM Corp., Armonk, NY, USA).

Results

Regarding pre- and postoperative parameters, postoperative FFMI ($15.5 \pm 2.6 \text{ kg}/\text{m}^2$) was significantly higher than preoperative ($15.3 \pm 2.4 \text{ kg}/\text{m}^2$, $P = 0.004$). Postoperative muscle volume of the gluteus maximus ($51.1 \pm 9.2 \text{ mm}^2/\text{kg}$) and quadriceps ($70.6 \pm 13.1 \text{ mm}^2/\text{kg}$) were significantly higher than preoperative volume (gluteus maximus; $45.9 \pm 10.4 \text{ mm}^2/\text{kg}$, $P = 0.004$, quadriceps; $65.5 \pm 13.1 \text{ mm}^2/\text{kg}$, $P < 0.001$). No significant difference was seen between pre- and postoperative FMI ($8.3 \pm 2.8 \text{ kg}/\text{m}^2$ vs $8.3 \pm 2.5 \text{ kg}/\text{m}^2$), PhA (4.4 ± 0.7 degrees vs 4.4 ± 0.7 degrees), and HU of both the gluteus maximus (21 ± 13.5 vs 19.7 ± 16.4) and quadriceps (47.1 ± 8.3 vs 47.4 ± 8.4). This data is recorded in Table 2.

Table 2
Comparisons of pre- and postoperative parameters of body composition, muscle volume and Hounsfield units

| | Preoperation | Postoperation | P value |
|---|--------------|---------------|----------|
| FMI (kg/m ²) | 8.3 ± 2.8 | 8.3 ± 2.5 | 0.5 |
| FFMI (kg/m ²) | 15.3 ± 2.4 | 15.5 ± 2.6 | 0.004* |
| PhA (degrees) | 4.4 ± 0.7 | 4.4 ± 0.7 | 0.33 |
| Muscle volume of gluteus maximus (mm ² /kg) | 45.9 ± 10.4 | 51.1 ± 9.2 | 0.004* |
| HU of gluteus maximus | 21 ± 13.5 | 19.7 ± 16.4 | 0.16 |
| Muscle volume of quadriceps (mm ² /kg) | 65.5 ± 13.1 | 70.6 ± 13.1 | < 0.001* |
| HU of quadriceps | 47.1 ± 8.3 | 47.4 ± 8.4 | 0.6 |
| FMI: fat mass index, FFMI: free fat mass index, | | | |
| PhA: phase angle, HU: Hounsfield units | | | |
| *: Significant values (P < 0.05) | | | |
| All values are expressed as mean value ± standard deviation | | | |

Preoperative FMI negatively correlated with postoperative muscle volume of the gluteus maximus (P = 0.02) and quadriceps (P < 0.001). Additionally, preoperative FMI negatively correlated with HU of the gluteus maximus (P = 0.03) and quadriceps (P = 0.03) (Fig. 3). Preoperative FFMI positively correlated with postoperative muscle mass of the quadriceps (P = 0.02) (Fig. 4). Preoperative PhA positively correlated with postoperative muscle volume of the quadriceps (P = 0.001) and HU of the gluteus maximus (P = 0.03) and quadriceps (P = 0.001) (Fig. 5).

The intraobserver and interobserver muscle volumes were 0.995 (95% CI, 0.992–0.997) and 0.985 (95% CI, 0.958–0.993), respectively. The intraobserver and interobserver HU values were 0.996 (95% CI, 0.994–0.998) and 0.988 (95% CI, 0.973–0.994), respectively.

Discussion

Some reports evaluated muscle volume around the hip after THA using CT and reported that muscle volume was increased after THA [9, 10, 12, 13]. Our results also found significantly increased muscle volume after THA in the gluteus maximus and quadriceps. This may be because alleviation of hip pain leads to improvement of daily activity, which thus accelerates the increase of muscle volume. Conversely, in this study, HU of the gluteus maximus and quadriceps did not change from pre- to post-operation. Our surgical approach was intermuscular invasion between the gluteus medius and tensor fasciae latae, which prevented injury to the posterior muscles and quadriceps as well as adipose degeneration of the

muscles. This study only assessed the gluteus maximus and quadriceps because these muscles are essential for posture retention and gait and excluded other hip muscles, such as the gluteus medius, tensor fasciae latae, inter obturator, and external obturator, which could have been injured by the surgical approach.

Although CT can evaluate muscle volume and adipose degeneration, examination costs and radiation exposure are concerns, and CT can only assess muscle volume planarly. BIA has been used for evaluating metabolic disease and obesity and can assess body composition safely and simultaneously by taking advantage of microcurrent electricity [16, 32, 33]. BMI also has been used for assessing metabolic disease. However, metabolically health and abnormal obesity can not be distinguished, because the FMI and FFMI can not be distinguished by BMI [34]. Merchant et al. reported that FMI was associated with higher rate of sarcopenia, and there was a possibility that the FFMI and FMI were more useful for predicting functional outcome in prefrail patients than BMI [34]. Preoperative FMI was found to correlate with both muscle volume and fatty degeneration after THA in this study. Conversely, preoperative FFMI was only associated with the muscle volume of the quadriceps. From these results, a detailed assessment of body parameters may be important to assess postoperative muscle volume and degeneration. Additionally, preoperative FMI may be a better predictor of muscle volume and fatty degeneration around the hip after THA than FFMI.

PhA is affected by nutritional status [35] and several health indicators [36] and deeply related to muscle mass [24] and muscle quality [37]. Lower PhA values indicate an increase in the extra water and a decrease in muscle mass [38, 39]. PhA has also been associated with osteoarthritis severity [40], functional ability [23, 34, 41, 42], and Barthel's index [43]. It is reported that PhA was associated with muscle strength [44] and quadriceps strength [40]. Therefore, there is a possibility that PhA might be a useful predictor for screening physical function [45]. In this study, preoperative PhA correlated with postoperative HU of both the gluteus maximus and quadriceps, and muscle volume of the quadriceps. These results also indicate that preoperative PhA may be a useful prognostic tool for evaluating postoperative muscle volume and fatty degeneration around the hip. From our study, Preoperative interventions to decrease FMI (maintaining proper weight) and increase FFMI (maintaining and increasing skeletal muscle mass) and PhA (improving the nutritional balance) may have a positive impact on increasing muscle volume and preventing fatty degeneration of muscles.

There were some limitations to this study. First, this study was a retrospective study and the sample size was small. However, to the best of our knowledge, this study is the first report to assess body composition before and after THA. Thus, we believe that this study provides new insight into the prediction of skeletal muscle volume and adipose degeneration after THA. Second, our patients had multiple diagnoses, which may have influenced the muscle volume and adipose degeneration after THA. Third, although it has been reported that PhA varies dependent on BMI, the limited sample size restricted BMI variance in this study. Westphal et al. reported that PhA tended to increase when BMI was $< 35 \text{ kg/m}^2$ and decrease when BMI was $> 35 \text{ kg/m}^2$ [25]. PhA has also been inversely associated with percentage body fat [46] and the degree of obesity [47]. However, there was no patients whose BMI was $35 > \text{kg/m}^2$

and significant correlation between preoperative FMI and PhA was not seen in this study. Fourth, postoperative BIA analysis can be affected by THA, because BIA is based on the measurement of impedance of body tissues to an applied electric current of low intensity. Although the electric resistance of fat tissue is very high, the resistances of muscle tissue and metal are low. Thus, postoperative muscle mass may be overestimated. Although this factor could not be eliminated completely, we unified implantation to minimize the effect of the implant.

Conclusions

Preoperative body composition affects postoperative muscle mass after THA and adipose degeneration of the affected lower limb. Preoperative body composition may be useful for predicting postoperative muscle mass and adipose degeneration.

Abbreviations

ALS

Anterolateral supine

BIA

Bioelectrical impedance analysis

BMI

Body mass index

CSA

Cross-sectional area

FMI

Fat mass index

FFMI

Fat-free mass index

HU

Hounsfield unit

PhA

Phase angle

THA

Total hip arthroplasty

Declarations

Ethics approval and consent to participate

All procedures were performed in accordance with the guidelines of the Declaration of Helsinki and approved by the Institutional Review Board of Tokai University Hospital (approval number: 21R-

311). Informed consent was waived due to the retrospective nature of this study, which used extracted data from medical records.

Consent for publication

Not applicable.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

TU conceptualized and designed this study; TU and KY acquired and analyzed the data; TU drafted the article; MW critically revised the important intellectual content of the manuscript; all authors read and approved the final manuscript.

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Supplementary

Figures



Fig. 1 A device of body composition measurements

Figure 1

A bioelectrical impedance analysis device for body composition measurements

Bioelectrical impedance analysis takes advantage of noninvasive minute electric current ($100\mu\text{A}$) using two pairs of hand electrodes and two pairs of foot electrodes. This device (mBCA515; seca, Hamburg, Germany) can measure segmental skeletal muscle (right arm, left arm, trunk, right leg, left leg), fat mass index, fat-free mass index and phase angle simultaneously.

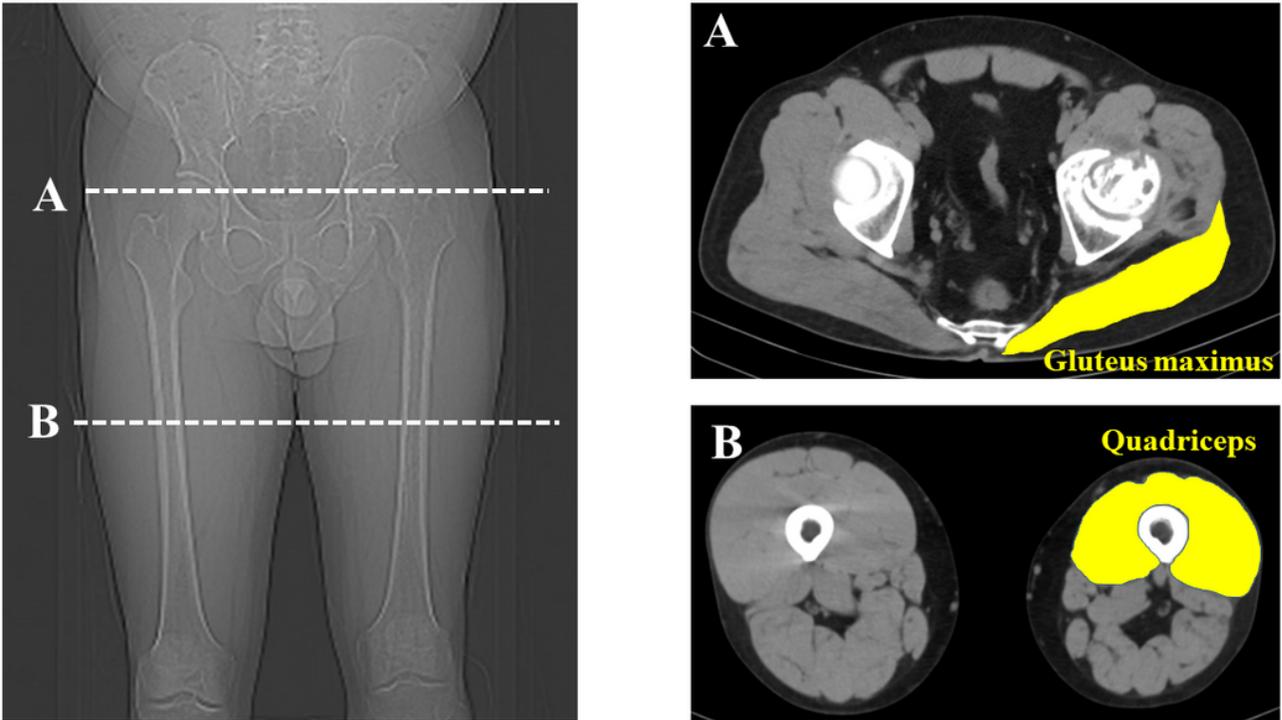


Fig. 2 Measurement of muscle volume and Hounsfield units

Figure 2

Measurement of muscle volume and Hounsfield units

Cross-sectional measurement of the gluteal maximus and quadriceps was performed using computed tomography (CT) images at the greater trochanter (A) and the middle of the thigh (B).

FMI

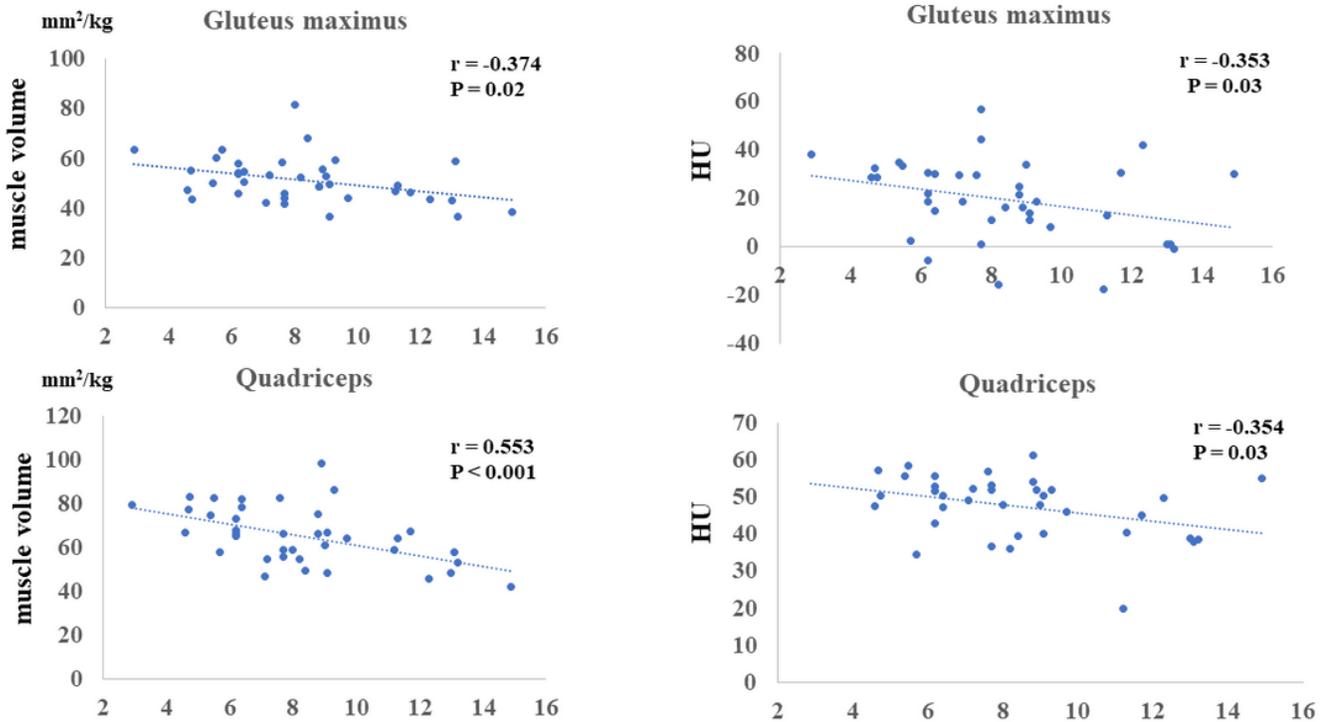


Fig. 3 Correlation between preoperative FMI with postoperative muscle volume and HU

Figure 3

Correlation between preoperative fat mass index and postoperative muscle volume and fatty degeneration

Preoperative fat mass index (FMI) was significant negatively correlated with postoperative muscle volume of the gluteus maximus and quadriceps and postoperative Hounsfield units (HU) of the gluteus maximus and quadriceps.

FFMI

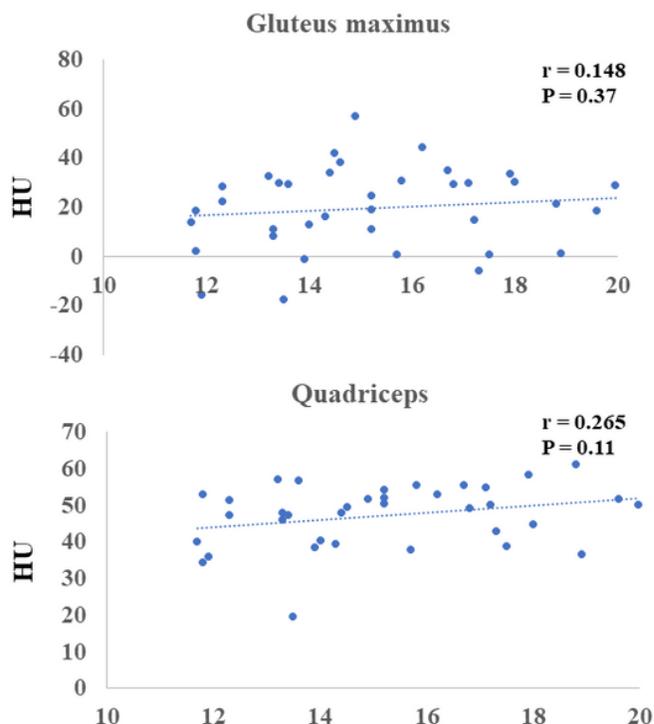
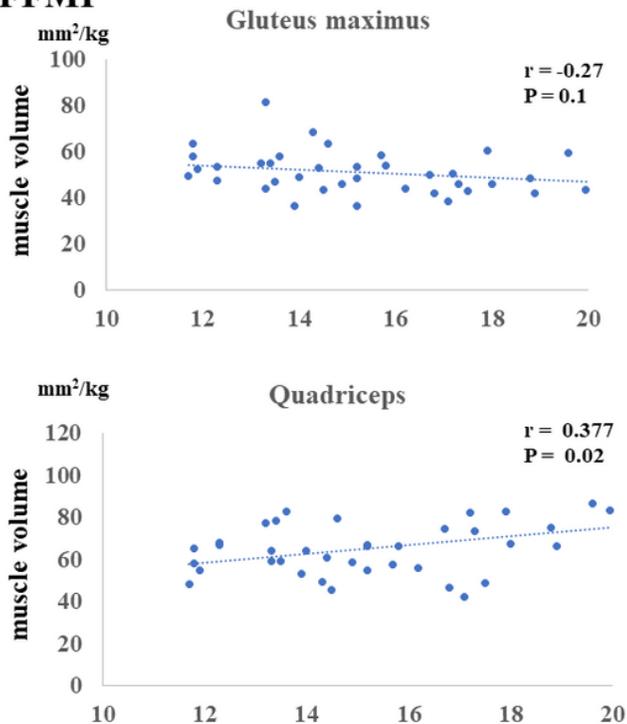


Fig. 4 Correlation between preoperative FFMI with postoperative muscle volume and HU

Figure 4

Correlation between preoperative fat-free mass index and postoperative muscle volume and fatty degeneration

Preoperative fat-free mass index (FFMI) was significant positively correlated with postoperative muscle volume of the quadriceps. Preoperative FFMI was not significantly correlated with postoperative Hounsfield units (HU) of the gluteus maximus or quadriceps.

PhA

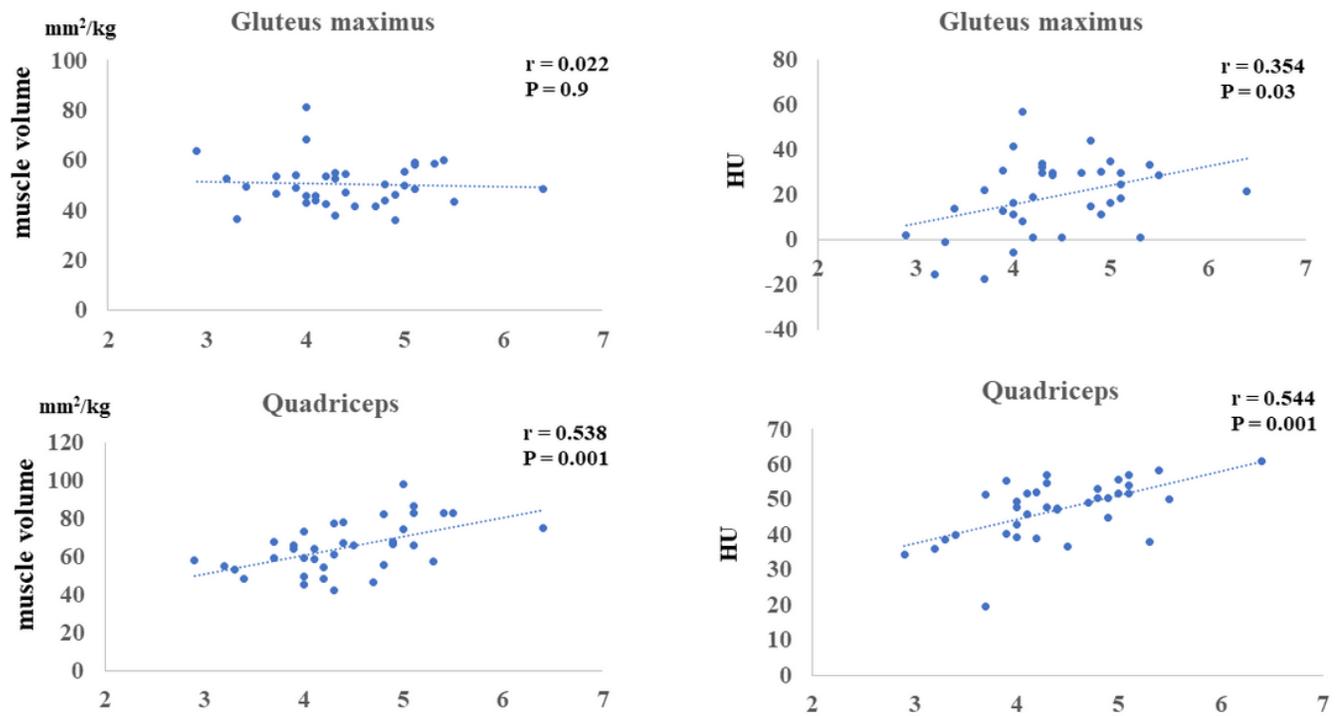


Fig. 5 Correlation between preoperative PhA with postoperative muscle volume and HU

Figure 5

Correlation between preoperative phase angle and postoperative muscle volume and fatty degeneration

Preoperative phase angle (PhA) was significant positively correlated with postoperative muscle volume of the quadriceps and postoperative Hounsfield units (HU) of the gluteus maximus and quadriceps.