Persisting muscle atrophy two years after replacement of the hip

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Muscle atrophy has been demonstrated in patients suffering from osteoarthritis of the hip, but little is known about muscular recovery after total hip replacement (THR). A total of 20 patients with unilateral osteoarthritis of the hip were assessed before, six months and two years after THR. The cross-sectional area and radiological density of the muscles of the hip, thigh, calf and back were measured using CT. We hypothesised that the muscles would not recover fully after operation.

After two years comparison of the limb with the THR with the healthy limb showed that there was such a reduction in the cross-sectional area in iliopsoas (7.0%; p = 0.006) and the hip adductors (8.4%, p = 0.003) and in the radiological density in gluteus maximus (10.1 Hounsfield units; p < 0.001), gluteus medius/minimus (5.6 Hounsfield units; p = 0.011), iliopsoas (3.9 Hounsfield units; p < 0.001) and the adductors (2.4 Hounsfield units; p = 0.022).

Thus, there was persistent muscle atrophy in muscles acting about the hip two years after THR. We suggest that an earlier operation or a more intensive rehabilitation may reverse these changes.

Minimally invasive surgical approaches may be used for total hip replacement (THR) in an attempt to reduce local soft-tissue damage. Although atrophy of the muscles of the thigh has been described in patients with osteoarthritis of the hip, the pattern of recovery of these muscles after THR is still largely unknown.

Muscle atrophy is conventionally measured as a loss of volume, indicated by a reduced cross-sectional area. However, an additional loss of contractile muscle can be inferred from the infiltration of fat as indicated by a reduced radiological density assessed in Hounsfield units. Fat infiltration of supraspinatus after a rotator-cuff tear has been deemed to be irreversible, and thus a negative prognostic factor for recovery. The altered composition of muscles in response to training and inactivity has been described and we have recently shown fat infiltration in the hip and thigh muscles pre-operatively in patients awaiting THR. However, its potential for reversal post-operatively has yet to be investigated.

Our aim therefore was to map out the natural history and quality of the muscle mass in the lower leg during the first two years after THR. We have previously reported the pre-operative measurements. We hypothesised that several muscles would not recover fully after rehabilitation, because of changes induced by chronic pre-operative inactivity.

Patients and Methods

As previously described, 22 patients, four men and 18 women, with a mean age of 67 years (54 to 77) who had unilateral osteoarthritis of the hip and were awaiting THR were consecutively recruited between January and May 2005. Their mean weight was 79 kg (57 to 114). Measurements were made on the day before surgery and at six months and two years after THR by an orthopaedic surgeon (AR) and the chief radiology assistant (MF). The patients had no previous surgery on the lower leg. Those with neurological and advanced cardiopulmonary disease or co-morbidity of the lower leg were excluded. One patient who sustained an operative femoral fracture and one whose operation was undertaken through a lateral approach were also excluded. All the remaining 20 patients had a posterior approach. At follow-up at six months there were three drop-outs (one muscular tear just before measurements, one patient was abroad and one patient did not want to attend) but at the follow-up at two years measurements were made in all 20 patients. One patient had an early post-operative hip dislocation which was treated in a brace for six weeks.

The mean duration of hip symptoms before surgery was 4.3 years (1 to 10). Either a cementless porous-coated, Bi-metric (n = 8, Biomet Inc,
Warsaw, Indiana), or a cemented polished tapered CPT (n = 12, Zimmer Inc, Warsaw, Indiana) femoral component was used. A cemented highly cross-linked polyethylene, Müller acetabular component (Stryker Howmedica Inc, Rutherford, New Jersey) was used in all patients. All were allowed early weight-bearing.

Clinical assessment was made using the Short-form (SF)-36,8 the Harris hip (HHS) 9 and Euroqol (EQ-5D) 10 scores. The past medical history, the duration of hip symptoms and the use of analgesic medications were noted. Hip pain was assessed using a visual analogue scale (VAS) with a range of 0 to 10, in which zero equalled no pain and ten unbearable pain as previously reported.2 All the patients completed ten sessions of weekly physiotherapy post-operatively and home exercises thereafter were encouraged. At the follow-up at two years training habits varied among the patients from none to exercises several times a week. The mean weight of the patients after two years (80 kg, 60 to 127) had not changed.

All the patients provided written informed consent and ethical approval had been obtained.

Computerised tomography. Muscle cross-sectional area and radiological density were assessed in muscles of the hip, thigh, calf and back bilaterally using transaxial CT (General Electric Spiral scan; GE Medical System, London, United Kingdom; 130 kV, 200 mAs, 1.5 s scan time) as previously described (Fig. 1). The radiation dose was minimised by limiting scan volumes through anatomical landmarks on scout images.

Goodpaster et al3 carried out repeated CT measurements and demonstrated a coefficient of variability (CV%) of < 1% in the radiological density of thigh and calf muscles. We have previously found a CV% of the cross-sectional area in thigh and calf muscles of less than 2%.11 We have not found any data on methodological errors of tomographic assessment of hip muscle, but since circumscribing these large muscle bellies is easy and the bony landmarks of the pelvis are also easily identified, we have no reason to believe that the error in the measurements differs.

Statistical analysis. This was performed using the paired t-test or ANOVA for single measures, setting the significance level at \( p \leq 0.05 \). For repeated measures, a two-factor ANOVA (limb \( \times \) time) was used, with a lower significance level at \( p < 0.03 \), when an error rate for multiple comparisons of simple main effects was calculated partitioning the family of the main factors and the interaction term (0.05 \( \times \) 3 = 0.15) and dividing by five planned comparisons.12

Results

When compared with the healthy limb, the pre-operative cross-sectional area was reduced by between 4.5% and 15.2% (p < 0.03) in all muscles except gluteus medius/minimus and the plantar flexors of the ankle, and the radiological density was reduced by between 2.7 and 13.8 Hounsfield units in all muscles except the ankle plantar flexors.

At the follow-up at six months the mean cross-sectional area was still reduced (3.7% to 11.3%) in all muscles except gluteus medius, the hamstrings and the plantar flexors of the ankle and the mean radiological density was reduced (3.6 to 13.7 Hounsfield units) in all muscles except the ankle plantar flexors.

At two years a reduced cross-sectional area persisted in iliopsoas (7.0%; \( p = 0.006 \)) and the hip adductors (8.4%; \( p = 0.003 \)) and there was a reduced radiological density in gluteus maximus (10.1 Hounsfield units; \( p < 0.001 \)), gluteus medius/minimus (5.6 Hounsfield units; \( p = 0.011 \)), iliopsoas (3.9 Hounsfield units; \( p < 0.001 \)) and the adductors (2.4 Hounsfield units; \( p = 0.022 \)). Changes in the cross-sectional area and radiological density over time for both lower limbs are shown in Figures 2 and 3. In the limb with THR the cross-sectional area increased in the adductors, iliopsoas, vastii and hamstrings. The radiological density...
increased in gluteus medius/minimus, the adductors, vasti and hamstrings, and decreased in gluteus maximus and the back extensors.

In the healthy limb the mean radiological density decreased in gluteus maximus, the adductors, iliopsoas, vasti and hamstrings, while the cross-sectional area showed no change over two years. There was no difference in the cross-sectional area or the radiological density of the extensor muscles of either side of the back at any occasion (Table I). Post-operatively, there were no changes in the mean cross-sectional area but the radiological density was reduced both at six months and two years (Table I).

Intra-observer reproducibility between two separate measurements varied between 0.4% and 4.1% and for the cross-sectional area and between 0.3% and 2.0% for the radiological density. Interobserver reproducibility was between 1.4% and 6.2% and 0.9% and 2.1%, respectively.

The variation (intra- and interindividual) of measurements

| Table I. The mean values (SD), differences and p-values for the cross-sectional area (CSA) (mm²) and radiological density (RD), Hounsfield units (HU). The limb with the THR compared with the healthy limb pre-operatively, and at six months and two years post-operatively |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Muscle                      | OA*             | Healthy         | Diff (%)†       | p-value         | OA*             | Healthy         | Diff (HU)       | p-value         |
| Gluteus maximus             |                 |                 |                 |                 |                 |                 |                 |                 |
| Pre-operative              | 3220 (813)      | 3691 (864)      | 12.2            | < 0.001‡       | 16.8 (16.9)     | 29.3 (11.9)     | 12.5            | < 0.001†       |
| 6 months                   | 3449 (949)      | 3691 (916)      | 6.5             | 0.011‡         | 13.4 (15.9)     | 27.1 (11.7)     | 13.7            | < 0.001†       |
| 2 years                    | 3482 (969)      | 3614 (960)      | 3.2             | 0.154          | 15.3 (17.2)     | 25.4 (14.0)     | 10.1            | < 0.001†       |
| Gluteus medius/minimus     |                 |                 |                 |                 |                 |                 |                 |                 |
| Pre-operative              | 4587 (954)      | 4624 (987)      | 0.6             | 0.589          | 19.3 (14.3)     | 33.1 (11.2)     | 13.8            | < 0.001†       |
| 6 months                   | 4469 (1132)     | 4511 (1026)     | 1.1             | 0.687          | 20.7 (12.1)     | 32.3 (11.0)     | 11.6            | < 0.001†       |
| 2 years                    | 4542 (1115)     | 4567 (967)      | 0.8             | 0.799          | 25.5 (11.8)     | 31.1 (12.7)     | 5.6             | 0.011†         |
| Adductors                  |                 |                 |                 |                 |                 |                 |                 |                 |
| Pre-operative              | 1849 (649)      | 2181 (667)      | 15.2            | < 0.001        | 35.4 (10.1)     | 43.2 (6.0)      | 7.8             | < 0.001†       |
| 6 months                   | 2002 (654)      | 2268 (739)      | 11.3            | < 0.001        | 35.5 (9.0)      | 42.0 (6.0)      | 6.5             | < 0.001†       |
| 2 years                    | 2057 (680)      | 2255 (724)      | 8.4             | 0.003‡         | 39.2 (7.8)      | 41.6 (6.5)      | 2.4             | 0.011†         |
| Iliopsoas                   |                 |                 |                 |                 |                 |                 |                 |                 |
| Pre-operative              | 1086 (305)      | 1271 (370)      | 13.8            | < 0.001        | 55.6 (9.0)      | 61.8 (5.3)      | 6.2             | < 0.001†       |
| 6 months                   | 1132 (299)      | 1272 (341)      | 10.4            | < 0.001        | 55.0 (7.8)      | 60.5 (5.4)      | 5.5             | < 0.001†       |
| 2 years                    | 1164 (305)      | 1262 (338)      | 7.0             | 0.006          | 55.9 (6.5)      | 59.8 (6.0)      | 3.9             | < 0.001†       |
| Vasti                       |                 |                 |                 |                 |                 |                 |                 |                 |
| Pre-operative              | 3902 (1174)     | 4497 (1095)     | 13.7            | < 0.001        | 47.4 (9.0)      | 52.4 (5.7)      | 5.0             | < 0.001†       |
| 6 months                   | 4186 (1187)     | 4460 (1172)     | 6.0             | 0.009‡         | 47.2 (7.4)      | 51.2 (5.5)      | 4.0             | < 0.001†       |
| 2 years                    | 4388 (1194)     | 4475 (1156)     | 1.8             | 0.200          | 49.3 (6.9)      | 50.7 (6.0)      | 1.4             | 0.118          |
| Hamstrings                  |                 |                 |                 |                 |                 |                 |                 |                 |
| Pre-operative              | 2416 (434)      | 2684 (486)      | 9.4             | < 0.001        | 31.7 (10.1)     | 38.0 (8.0)      | 6.3             | < 0.001†       |
| 6 months                   | 2623 (468)      | 2708 (478)      | 2.9             | 0.091          | 32.3 (8.5)      | 36.5 (7.8)      | 4.2             | < 0.001†       |
| 2 years                    | 2660 (539)      | 2725 (499)      | 2.1             | 0.406          | 34.9 (8.5)      | 36.0 (8.1)      | 1.1             | 0.119          |
| Ankle plantar flexors      |                 |                 |                 |                 |                 |                 |                 |                 |
| Pre-operative              | 4157 (786)      | 4295 (837)      | 2.7             | 0.106          | 35.7 (8.1)      | 38.4 (6.9)      | 2.7             | 0.018‡         |
| 6 months                   | 4210 (850)      | 4386 (951)      | 3.3             | 0.042          | 36.4 (7.8)      | 37.5 (6.9)      | 1.1             | 0.289          |
| 2 years                    | 4296 (931)      | 4411 (980)      | 2.0             | 0.183          | 37.2 (7.7)      | 37.7 (7.0)      | 0.6             | 0.615          |
| Ankle dorsal flexors       |                 |                 |                 |                 |                 |                 |                 |                 |
| Pre-operative              | 1384 (254)      | 1457 (300)      | 4.5             | 0.015‡         | 46.7 (7.8)      | 50.7 (6.4)      | 4.1             | < 0.001†       |
| 6 months                   | 1397 (250)      | 1460 (305)      | 3.7             | 0.019‡         | 46.5 (6.7)      | 50.1 (6.7)      | 3.6             | < 0.001†       |
| 2 years                    | 1410 (251)      | 1457 (303)      | 2.5             | 0.108          | 48.2 (6.9)      | 50.1 (7.0)      | 1.9             | 0.049†         |
| Back extensors             |                 |                 |                 |                 |                 |                 |                 |                 |
| Pre-operative              | 2222 (377)      | 2174 (357)      | 2.4             | 0.222          | 19.6 (11.2)     | 18.3 (12.9)     | 1.3             | 0.643          |
| 6 months                   | 2240 (385)      | 2180 (326)      | 2.7             | 0.129          | 16.9 (12.1)     | 16.0 (12.5)     | 0.9             | 0.790          |
| 2 years                    | 2251 (398)      | 2204 (350)      | 2.2             | 0.233          | 16.6 (11.9)     | 16.2 (13.2)     | 0.5             | 0.877          |

* osteoarthritis
† values shown are means of individual side differences
‡ significant difference (two way ANOVA, p < 0.03)
was similar for all sites along the limb, but small muscles showed higher variation.

The mean HHS, EQ-5D and VAS all improved (p < 0.001) from 51.6 (33.6 to 65.1), 0.44 (0.03 to 0.69) and 5.2 (0 to 8) pre-operatively to 86.2 (45.6 to 99.9), 0.85 (0.03 to 1.0) and 0.05 (0 to 1), respectively, at follow-up at two years. Two years after surgery the SF-36 had improved (p < 0.001) for all domains except for general health (p = 0.11). Pre-operative values are presented in Figure 4: physical function 29.3 (10 to 60), role physical 9.1 (0 to 41), general health 65.0 (25 to 97), vitality 46.6 (10 to 85), social function 63.1 (25 to 100), role emotional 36.4 (0 to 100) and mental health 68.9 (28 to 92). Two years post-operatively those values were as follows: physical function 72.7 (20 to 95), role physical 77.3 (0 to 100), body pain 79.8 (31 to 100), general health 71.9 (25 to 100), vitality 70.6 (13.3 to 100), social function 89.8 (25 to 100), role emotional 86.4 (0 to 100) and mental health 86.2 (52 to 100).
Discussion

Our study was the first to describe the relationship between the hip, knee and calf muscles after THR. The most striking finding was that the marked pre-operative atrophy of muscles acting about the arthritic hip continue for the first two years after THR. Fat infiltration of the muscles was slower to recover than size. The muscles of the lower leg showed minor differences in fat infiltration and size.

It has been shown that healthy volunteers subjected to bedrest for five or six weeks have profound atrophy of the extensor muscles of the knee and the plantar flexors of the ankle whereas the knee flexors and the gluteal muscles show only a modest loss. This was thought to be due to differences in gravitational load with more severe changes in the distal muscle groups. Our data in patients with osteoarthritis of the hip showed the opposite pattern, with no differences in atrophy between the extensor and flexor muscles of the calf, thigh or hip and the hip muscles markedly affected both before and after THR. These findings suggest that weight-bearing is not the prime determinant of muscular adaptation to osteoarthritis of the hip, or that only muscles acting about the painful hip are unloaded while calf muscles maintain full weight-bearing.

Pre-operative muscle atrophy in the lower limb of patients with osteoarthritis of the hip has been described previously by us and others, but existing post-operative data are limited to the thigh muscles. Full recovery has been suggested after traditional rehabilitation or specific training. Our long-term data confirm these findings in muscles acting about the knee and ankle, whereas those of the hip do not seem to recover at the same rate. The explanation for this discrepancy remains obscure.

Goodpaster et al showed that a reduced radiological density could be used as a semi-quantitative measure of fat deposit in muscle, in which a loss of one Hounsfield unit would correspond to at least the same percentage of increased fat. In the limb with THR we found more fat infiltration in the gluteal muscles (13 to 15 Hounsfield units difference; Table I) than in those of the thigh (5 to 8 Hounsfield units) or calf (3 to 4 Hounsfield units) when compared with the healthy limb. This suggested further muscle atrophy around the affected hip which was not revealed by measurement of the cross-sectional area. In order to illustrate the time course of post-operative recovery of different muscle groups, the changes in the cross-sectional area and radiological density are shown in four graphs (Figs 2 and 3). P-values are shown in Table II. There is a less rapid recovery in radiological density than in the cross-sectional area, which may explain the slower recovery of the hip muscle mass. Six months after THR there was no change in the radiological density of the muscles around the hip and only minor recovery of muscle as indicated by increased cross-sectional area values. However, the extensors of the knee and calf muscles which showed less pre-operative differences in intramuscular fat between the two sides, recovered about half their atrophy six months post-operatively, and almost fully after two years (Table I). Our data expand and support the findings by shoulder surgeons in that fat infiltration is a strong negative predictor of muscle recovery.

However, in patients with unilateral osteoarthritis of the hip it is often assumed that the healthy limb is weakened because of inactivity, and that equal recovery in both limbs should be anticipated after surgery. We found no post-operative changes in muscle cross-sectional area and only a minor decrease in radiological density (1 to 4 Hounsfield units) in the healthy limb, and therefore it was tempting to regard that limb as the internal control for the limb with the THR. We would need to study a group of external age- and gender-matched control subjects for an unbiased comparison. However, the large number of healthy subjects which would be needed to...
obtain statistical power, and the resulting radiation dose would impose major limitations on that experimental design. The reduced radiological density is slow to recover in individual limbs (Fig. 3, Table I). The lack of improvement in the healthy limb merits an explanation. It may be that patients remain relatively inactive even after a successful THR. Alternatively, it may be speculated that the muscles of the healthy limb are relatively overloaded during the pre-operative years of painful osteoarthritis.

The surgical trauma of THR may reduce the effect of post-operative rehabilitation. Suëtta et al.17 reported a loss of 13% and 9% in the quadriceps of cross-sectional area at one and three months, respectively, after THR with standard rehabilitation. We did not have those early data points and could only speculate that the modest recovery shown six months after THR was affected by the catabolic response of surgery. The operative technique may influence both the surgical trauma and the conditions for rehabilitation. All our patients were operated on using the posterior approach in which gluteus maximus was bluntly separated in the proximity of the motor nerve (branches of the inferior gluteal nerve). A slower recovery of traumatised or denervated muscles might have been expected, but gluteus maximus showed the same delayed recovery as other hip muscles. This might suggest that the incision does not determine the recovery of muscles which are atrophied in patients with osteoarthritis of the hip. Long-term studies on the different surgical approaches including less invasive techniques may shed light on this issue.

These patients had symptoms for a mean of four years, and the atrophic process had probably started earlier. The abnormalities including fat infiltration may contribute to the impaired function reported by some patients after THR.18 Earlier operation may prevent the development of these changes and fatty infiltration may be reversed by intensive rehabilitation.

The generic (SF-36, EQ-5D) and disease-specific (HHS) health scores were collected to confirm that our small sample was representative of patients with osteoarthritis of the hip. The SF-36 values before and after THR, and the gains in the EQ-5D were similar to those which have been previously reported,19 and the values after two years did not differ from those of an age-matched healthy population.20 The remaining muscle atrophy, however, seems not to be related to these clinical scores, and they may not reflect the same qualities.

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