

Correlation between pain and weakness of vastus medialis evaluated by ultrasound in total knee arthroplasty

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Abstract

Osteoarthritis leads to articular cartilage destruction.

The treatments reduce pain and improve function by using physical therapy, anti-inflammatory drugs, and surgical intervention, when necessary.

Several studies suggest that 30% of patients undergoing knee replacement are not satisfied with results, thus highlighting a possible correlation with quadriceps strength and activities of daily living performance.

Some authors studied the connection between clinical and radiological variables and quadriceps thickness, measured by ultrasound in patients with knee replacement.

We conducted a cross-sectional study, enrolling 28 patient submitted to the same rehabilitation protocol (4 weeks), after knee arthroplasty, evaluated at admission (T0) and discharge, (TF), using ultrasound for measurement of vastus medialis thickness, and functional scales for abilities and pain.

We noted that patients with a cross-sectional diameter of vastus medialis larger than 10 millimetres at the admission manifested less pain and improved their function and abilities values at TF compared to patients with a cross-sectional diameter smaller than 10 millimetres, and showed a better recovery process.

Our study demonstrates that the weakness of vastus medialis could be an independent factor which can impact the outcome of patients submitted to arthroplasty of knee, and that it can be evaluated using ultrasound.

Introduction

Osteoarthritis is a common cause of disability. This degenerative joint disease is characterized by synovial membrane inflammation, and subchondral bone remodelling, leading to articular cartilage destruction.

The main treatment goals are to alleviate pain and improve function using physical therapy, anti-inflammatory drugs, and surgical intervention, when necessary.

The most commonly affected joint is the knee,¹ therefore a common procedure performed for end-stage osteoarthritis, especially in elderly individuals, is total knee arthroplasty.

In Italy, in 2018, 28,038 surgeries were performed. 84.4% were total knee replacements vs 15.6% unicompartmental. A unicompartmental knee arthroplasty (UKA) is a surgical procedure used to relieve disease in one of the knee compartments. In UKA, only the damaged parts of the knee are replaced. The UKA surgery may reduce postoperative pain and have a shorter recovery period than a total knee replacement procedure, especially in the elderly population. Primary osteoarthritis has been indicated as the main reason for surgery (94.9%), with a 2:1 ratio between females and males, and an the most-affected age group includes 65-74 years old individuals.²

A problem in elderly patients is a well-documented loss of muscle mass and strength. Studies reported that this loss increases progressively, can be aggravated by acute or chronic illnesses³ and be a predictive factor for immobilization, physical disability and increased mortality.⁴

The goal of total knee arthroplasty is to reduce pain and improve function and quality of life. However, the indications and ideal time of the surgery is not standardized or well-defined.⁵ In any case, some studies suggest that 30% of patients undergoing knee replacement are not satisfied with the outcome.⁶

Rehabilitation after knee replacement seems to influence outcomes. Some investigators suggested that an intensive and prolonged rehabilitation could accelerate functional recovery.⁷ However, some unchangeable factors also have an impact on functional outcomes,⁸ such as gender, age, chronic diseases. The

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clinical exam, pain, and quadriceps strength are variable factors.⁹ Other authors noted that older age does not seem to influence the outcome, and underlined that some patients aged 75 years and older reported significantly better pain relief after joint replacement than younger patients.¹⁰ Furthermore, a few studies highlight that a knee flexion from 105° to 113° ROM should make it possible to perform the majority of tasks of daily living.¹¹

The average age of the population in our study was 69.96, they were mainly females and no patient had health conditions as chronic diseases that could affect to recovery process. As is well-known, muscle strength decreases progressively in older age, and this is associated with physical disability, especially in people aged 80 years and over.¹² Some studies showed a positive correlation with strength quadriceps and ADL performance.¹³ Sarcopenia is well documented in the elderly, and quadriceps weakness is involved in the progression of knee osteoarthritis.¹⁴ Muscle weakness is attributed to a failure of voluntary muscle activation. In this respect, some studies showed that quadriceps strength declines after knee replacement and recovery to previous levels is rare.^{15,16} During first month after surgery, atrophy is reported in 5-20% of cases compared to preoperative values.¹⁷

A positive association between quadriceps strength and ADL performance was confirmed by studies which showed that training is helpful to improve physical function.¹⁸

Actually, the use of ultrasound seems important to evaluate quadriceps muscle thickness and quality of subcutaneous fat, in order to determine the suitability of therapeutic options in knee osteoarthritis.

Ultrasound (US) of the musculoskeletal system is an accurate and reproducible system used routinely in various clinical and research fields. It is simple, non-invasive, and cost-effective compared with other imaging techniques. The repeatability between investigators using this technique was established for various, and the validity of muscle thickness measurement by using ultrasound vs MRI was also reported¹⁹.

Some authors studied the connection between clinical and radiological variables and quadriceps thickness measured by US in patients with knee osteoarthritis²⁰ and found negative correlations between the thickness of the quadriceps, age and function. Physical disability in old age is associated with low muscle strength, and a positive association between quadriceps strength and activities of daily living (ADL) performance was confirmed. However, the role of an optimal reliability program remains unclear.²¹

The correlation between knee replacement and pain is unclear, and only a few studies were focused on the loss of vastus medialis. Aily *et al.*²² investigated the differences in muscle architecture and muscle strength of the vastus lateralis muscle in people of different ages with and without knee osteoarthritis.

Muscle strength depends on muscle mass composition and structure. Thickness and the *pennation angle* are some parameters related to muscle strength.²³ The *pennation angle* is defined as the angle between muscle fibres and the deep fascia of the muscle. When the orientation of the fibres is not almost parallel to their fascia, this parameter cannot be determined. Muscle thickness is defined as the distance between two muscle bundles.

Muscle thickness and the pennation angle can be easily determined by ultrasound on the basis of muscle echogenicity.

The aim

The aim of our study was to evaluate the relationship between muscle thickness of vastus medialis, pain and function in patients who underwent knee arthroplasty.

A frequent problem in these patients submitted to knee arthroplasty is pain in the medial area of knee. Several studies investigated the role of various factors. We think that the weakness of vastus medialis could be correlated with it.

Another aim was to investigate the role of ultrasound in the assessment of strength, and muscle mass. These parameters are correlated to pennation angle, echogenicity and muscle thickness. Several studies investigated ultrasound as a technique to measure them, but their reproducibility in the quadriceps is hard to achieve. This is why we undertook to study this topic.

Materials and Methods

We conducted a cross-sectional study. Patients who met the following criteria were selected for the study: i) Male or female, aged between 57-85, dsubmitted to knee replacement admitted to our department of rehabilitation; ii) Hospital stay: 1 month.

Exclusion criteria were: poly-arthritis, rheumatoid arthritis or other systemic inflammatory arthropathies, any lower limb surgery within the last 12 months, neurologic or musculoskeletal conditions that affected balance or movement (*i.e.*, Parkinson disease, multiple sclerosis).

Each patient was evaluated at T0 (admission) and TF (discharge), after a 4-week rehabilitation treatment.

We used a N.R.S. scale (numeric rating scale), with a score from zero to 10 points in order to rate the pain value in the medial area of knee, and an analogic goniometer to measure the knee range of motion.

The M.R.C. scale (Medical Research Council)²⁴ evaluated the strength, this grades muscle power on a scale of 0 to 5 in relation to the maximum expected for strength. (unclear).

We used the M.R.C. scale (Medical Research Council) in order to evaluate the strength. This grades muscle power on a scale of 0 to 5 in relation to the maximum expected for strength.

For evaluation of functional abilities, we used two multidimensional scale: the WOMAC²⁵ (Western Ontario and McMaster Universities Index of Osteoarthritis), and F.I.M²⁶ (Functional Independence Measure).

The WOMAC (Western Ontario and McMaster Universities Index of Osteoarthritis) is a multidimensional scale divided into 3 subscales used for the evaluation of hip and knee. The test measure pain with a score range of 0-20, stiffness with a score range of 0-8, and physical function with a score range of 0-68.

The F.I.M scale is used for daily activities and investigates physical, psychological and social function. The scale used to assess a patient level of disability as well as a change in patient status in response to rehabilitation or medical treatment. It is based on an 18-item scale (the total score is 126) with a score range from 1 to 7 (1 = total assistance and 7 = complete independence) for each item.

Rehabilitation protocol

We submitted all patients to the same standard rehabilitation protocol to improve independence in activities of daily living (ADL) including quadriceps isometrics, hip extensor isometrics, and progressive walking training to improve knee ROM and ankle pumps to prevent secondary complications, such as deep vein thrombosis.

The protocol included exercise for three hours a day, 6 days a week for 4 weeks.

We used a acetaminophen (1 gram twice a day), when pain was

more than 4 of the n.r.s. (numeric rating scale), and low molecular weight heparin to prevent deep vein thrombosis. When necessary, we used ice in case of swelling and we monitored vital signs (blood pressure and heart rate) daily.

Ultrasound imaging acquisition

We acquired the ultrasound images in B-mode of the cross-section and longitudinal section of the thigh. The participants were in supine position lying with the hip in neutral position and their knees resting comfortably in extension near the natural resting position of 10°-20°. A towel roll under the knee was used for positioning, and patients were instructed to relax their muscles. Scans were performed at the superior pole of patella and in the medial area for evaluating the vastus medialis in its cross-section and longitudinal section. By ultrasound, we acquired our parameters: thickness, and pennation angle.

The thickness of the vastus medialis was measured between the inside edges of muscle borders, in order to correlate pain and strength.

The pennation angle, that is the angle between muscle fibres and the deep fascia of the muscle, was measured in the longitudinal sections of thigh. We saw that, after knee prosthesis, the muscle had a disarranged structure that could not be evaluated.

Table 1. Patients.

Sex	Age	PTG
F	72	ptg sx
F	66	ptg dx
M	80	ptg dx
M	67	ptg sx
F	67	ptg sx
M	57	ptg sx
M	80	ptg dx
M	57	ptg dx
F	67	ptg dx
F	85	ptg dx
F	59	ptg dx
F	69	ptg dx
F	70	ptg sx
F	72	ptg dx
F	59	ptg sx
F	65	ptg dx
M	79	ptg sx
F	79	ptg dx
F	72	ptg sx
M	58	ptg sx
F	71	ptg dx
F	83	ptg dx
F	65	ptg dx
F	79	ptg sx
F	77	ptg sx
F	72	ptg sx
F	63	ptg dx
M	69	ptg sx

Data analysis

We used the statistical functions of Windows- Excel® for data analysis. Pain, functionals, and strength were evaluated at baseline (T₀) and also before the 4-week treatment (TF).

We administered the scales, calculated the value averages at T₀ and TF, then we compared them using a paired-test, in order to assess if significance was achieved.

We used some diagrams in order to highlight the relations between pain, strength and abilities with the thickness of the vastus medialis to highlight the relation between pain and muscle thickness.

Finally, in order to underline the correlation between the thickness of the vastus medialis and pain, we calculated the colleration index (Pearson's index) at TF. To match the data, since the pain scale was in decimals, we transformed the millimetres of thickness into decimetres.

Results

During 2020 we enrolled 28 patients who underwent knee replacements (Table 1): mean age 69.96 (DS 8.09); men 8; women 20; left knee replacement 13; right knee replacement 15.

We evaluated pain (numeric rating scale), range of motion (goniometer), strength (Medical Research Council), thickness of vastus medialis (ultrasound) and functional and daily activities (Womac and F.I.M), at the admission (T₀) and discharge, 4 weeks after rehabilitation treatment (TF).

The mean values at T₀ were: N.R.S. 4.17; R.O.M. 64.14; M.R.C. 2.39; Thickness 10.94; F.I.M. 69.35; Womac 70.83.

Values at the admission (T₀) showed that thickness of medial vastus correlated with pain, and 10 millimetres represented a sort of set point. Patients with a cross-section of the vastus under 10 millimetres had more pain and less ability. Then, we selected and followed two group based of this value.

One group (Group 1) included 16 patients (Table 2), with a cross-section of the vastus in T₀ over 10 millimetres and had better function, daily activities and ROM: Mean age 68.25 (DV 8.29);

Table 2. Patients of Group One.

Sex	Age	PTG
F	72	ptg sx
F	66	ptg dx
M	80	ptg dx
M	67	ptg sx
F	67	ptg sx
M	57	ptg sx
M	80	ptg dx
M	57	ptg dx
F	67	ptg dx
F	85	ptg dx
F	59	ptg dx
F	69	ptg dx
F	70	ptg sx
F	72	ptg dx
F	59	ptg sx
F	65	ptg dx

Men 5; Female 11; Left knee replacement 6; Right knee replacement 10.

Their mean values at T0 were (Figure 1): N.R.S. 3.12; R.O.M. 69.75; M.R.C. 2.62; Thickness 11.75; F.I.M. 68.75; Womac 57.38.

The other group (Group 2) included 12 patients (Table 3), who had a cross-section of the vastus in T0 under 10 millimetres (Mean age 72.25 (DV 7.55); Men 3; Female 9; Left knee replacement 7; Right knee replacement 5) with worse parameters (Figure 2): N.R.S. 5.58; R.O.M. 56.66; M.R.C. 2.08; Thickness 6.66; F.I.M. 70.1; Womac 76.59.

After 4 weeks, we evaluated all parameters in the two groups.

Mean values at TF of all patients were (Table 4): N.R.S. 0.57; R.O.M. 96.75; M.R.C. 3.53; Thickness 12.54; F.I.M. 110.28; Womac 30.54.

We noted that at TF Group 1 (Table 5) showed better values compared to Group 2 (Table 6) with better recovery. Mean values Group 1 at TF were (Figure 3): N.R.S. 0.25; R.O.M. 100.56; M.R.C. 3.75; Thickness 13.68; F.I.M. 111.56; Womac 19.06. Mean values for Group Two at TF were: N.R.S. 1; R.O.M. 91.66; M.R.C. 3.25; Thickness 10.25; F.I.M. 108.58; Womac 42.02.

All patients treated with our protocol had an improvement of motor abilities and function, with decreasing pain. The t-paired test showed that the improvement of values reached statistical

significance ($P < 0.01$) in all patients, but it was higher in patients in group 1, who at admission (T0) had better condition of vastus (11.75 mm vs 6.6 mm).

Table 3. Patients of Group 2.

Sex	Age	PTG
M	79	ptg sx
F	79	ptg dx
F	72	ptg sx
M	58	ptg sx
F	71	ptg dx
F	83	ptg dx
F	65	ptg dx
F	79	ptg sx
F	77	ptg sx
F	72	ptg sx
F	63	ptg dx
M	69	ptg sx

Group 1 T0

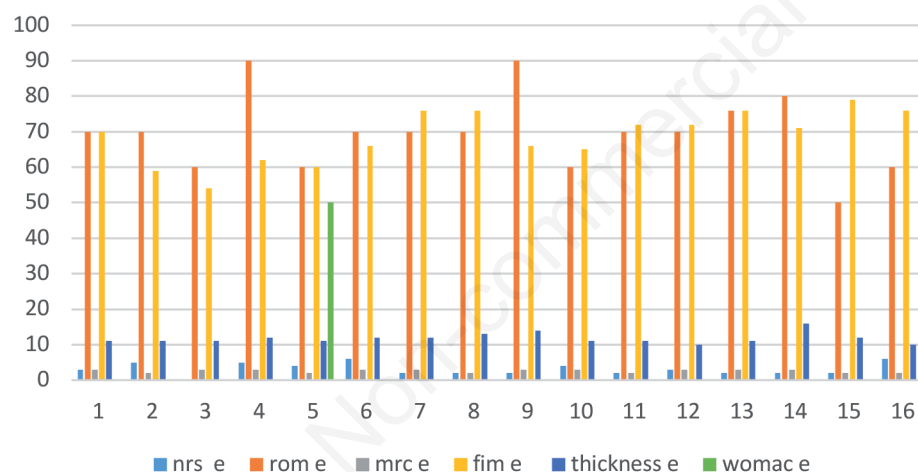


Figure 1. Group 1 T0.

Group 2 T0

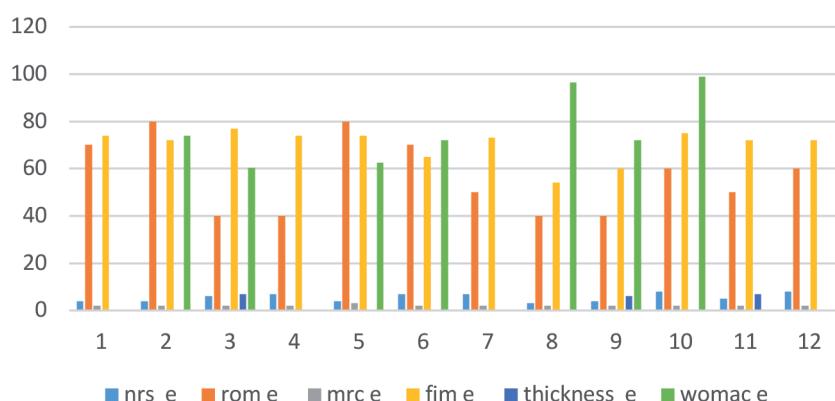


Figure 2. Group 2 T0.

At TF, the average of N.R.S. of Group 1 was 0.25 vs 1 group 2, R.O.M (range of motion) was 100.56, (91.66 in Group 2) and the functional scale showed better results. The average of F.I.M. was 11.56 vs 108.28 of Group 2, Womac was 19.06 vs 42.02.

It was possible to identify a correlation between the thickness of vastus medialis, pain and the recovery process in our patients (Figure 4). The Pearson's Index at TF between pain and thickness was 0.70, and the diagrams showed that, when the thickness of the vastus is high, pain in the medial area of knee is less intense, and this was more evident in group 1 (Figures 5 and 6).

It is important to note that in the literature a definition is given for the role of quadriceps and the effect on pain and disability, but it is still unclear what is the thickness of muscle, below which this correlation becomes evident. We saw that the effects become more evident below a value of 10 millimetres of thickness.

Furthermore, all muscle-related measurements of muscle were taken using ultrasound. Therefore, we saw that this technique provided precise results, was simple to use and non-invasive and could be used to assess muscle mass as well as architecture and composition.²⁷

It provided information on muscle thickness and echogenicity, showing that the uneven pattern of the fibres made it impossible to define *penation angle*. However, it allowed us to correlate muscle

thickness measurements with strength and pain, thus providing results about the recovery process.

Discussion

Osteoarthritis affects millions of people worldwide and involves several joints. The main signs, and symptoms are pain, loss of flexibility, stiffness and swelling. Risk factors are well-known such as obesity, age, sex, joint injuries and bone deformities. Medical treatments and physiotherapy can reduce pain and improve movement. Joint replacement surgery is recommended if those treatments are ineffective, with severe pain, disability and poor quality of life. Strong evidence shows that most patients have a reduction in pain and improve their function after total knee replacement.

Approximately 20% of patients suffer from chronic pain after

Table 4. Functional parameters TF (all patients).

NRS U	ROM U	MRC U	FIM U	THICKNESS U	WOMAC U
0	110	4	104	12	13.54
0	100	4	109	13	17.70
0	90	4	108	13	26,07
0	110	3	119	13	12,05
2	90	4	118	13	31.25
0	100	4	110	17	7.2
0	100	4	110	15	9.37
0	90	4	110	15	15.62
0	90	4	109	14	9.37
0	110	4	112	13	7.2
0	110	4	113	13	17.70
0	100	4	112	12	16.32
0	119	4	119	13	9.37
2	110	3	112	17	16.30
0	90	3	110	14	10.41
0	90	3	110	12	16.30
0	100	4	108	9.5	62.5
0	100	3	104	9.2	56,25
0	90	4	115	8	40.62
0	100	3	116	12	26.04
0	110	4	110	12	27,8
0	90	3	115	9	26.04
2	90	3	110	9	26.02
2	90	3	110	8.5	76.04
0	90	3	113	8.5	52.08
2	80	3	102	12	31.25
4	80	3	100	10	60.41
2	80	3	100	10	31.25

Table 5. TF-Functional Parameters Group 1.

NRS U 1	MRC U 1	FIM 1	WOMAC 1	THICKNESS
0	4	104	13.54	12
0	4	109	17.70	13
0	4	108	26.07	13
0	3	119	12.05	13
2	4	118	31.25	13
0	4	110	7.2	17
0	4	110	9.37	15
0	4	110	15.62	15
0	4	109	9.37	14
0	4	112	7.2	13
0	4	113	17.70	13
0	4	112	16.32	12
0	4	119	9.37	13
2	3	112	16.30	17
0	3	110	10.41	14
0	3	110	16.30	12

Table 6. TF-Functional Parameters Group 2.

NRS 2	MRC 2	FIM 2	WOMAC 2	THICKNESS
0	4	108	62.5	9.5
0	3	104	56.25	9.2
0	4	115	40.62	8
0	3	116	26.04	12
0	4	110	27,8	12
0	3	115	26.04	9
2	3	110	26.02	9
2	3	110	76.04	8.5
0	3	113	52.08	8.5
2	3	102	31.25	12
4	3	100	60.41	10
2	3	100	31.25	10

total knee arthroplasty.²⁸ The causes for this pain are not yet understood, however they are evidently associated with a multifactorial aetiology. The complex nature of this symptom and interactions between multiple risk factors make it difficult to predict who are the patients at risk of chronic pain.

Our study investigated the correlation with pain and loss of vastus medialis.

The effects of muscle loss in older age are well known. After age 30 from 3% to 5% of the muscle mass declines and contributes to fragility, falls and fractures in older adults. When muscle loss is present, it is followed by a reduction of strength and physical performance.

The aim of our study was to correlate thickness of vastus medialis and pain in patients who underwent knee arthroplasty, understand if this can influence functions and abilities and lastly demonstrate if this can be evaluated by ultrasound.

After knee replacement our patients had pain in the medial area. On the basis of data analyses we divided the patients into two

group, one with a cross-section diameter of vastus medialis over 10 millimetres, and the other under 10 millimetres.

All patients followed the same rehabilitation protocol and achieved improved values. Comparing the data, we noted a statistically significant improvement at TF in both groups (Figure 7), but especially in first.

The first group showed better functional and pain values compared to other group both at T0 and TF ($P < 0.01$). The patients of the second group had more pain than the first one, and their functions and abilities were worse ($P < 0.01$).

As shown in the literature, we think that the quadriceps muscle is fundamental to functional knee joint stability, and is highly involved in the biomechanics of the knee. Several studies reported a correlation between quadriceps strength and the progression of knee osteoarthritis²⁹ This muscle was generally weaker in patients with advanced knee osteoarthritis due to failure of voluntary muscle activation. This impairment seems to influence the recovery process after knee arthroplasty. When it is

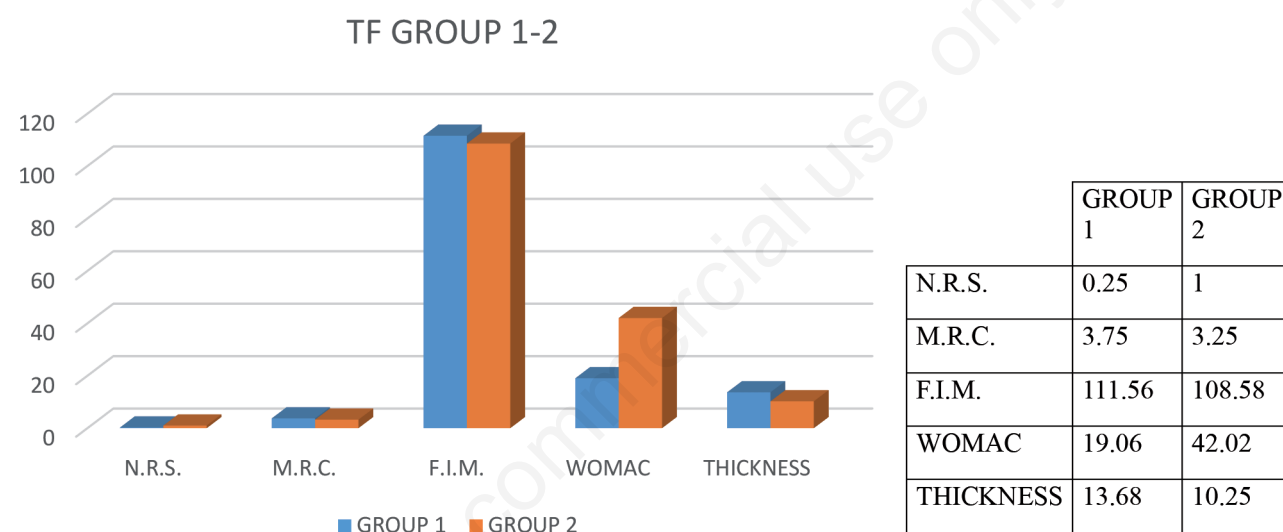


Figure 3. TF Group 1-2.

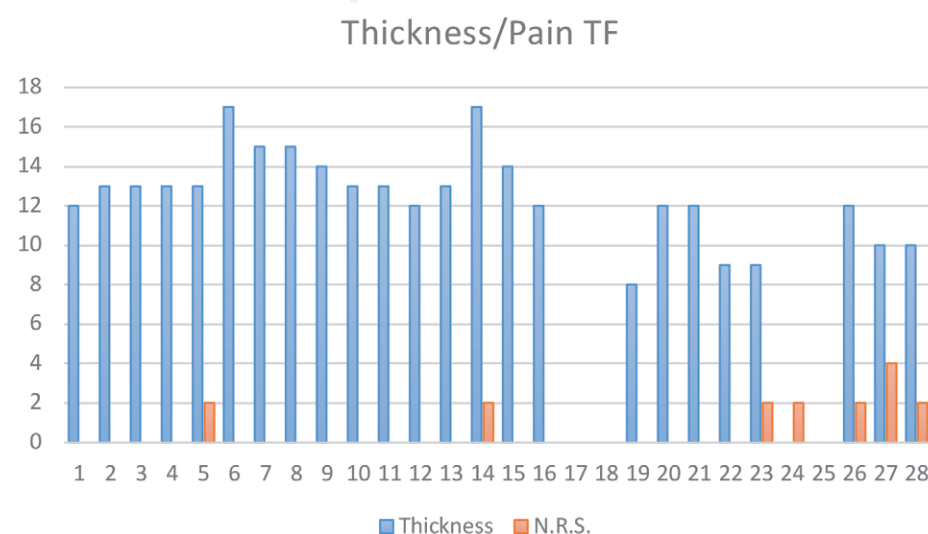


Figure 4. Thickness/Pain TF.

present, it correlates with pain in medial area of knee, and functional parameter are worse.

In our study we correlated pain and functional parameters to thickness of vastus, and saw that the patients with a cross-sectional

diameter greater than 10 millimetres at hospital admission experienced less pain and had improved functional and ability values after 4 weeks of treatment compared to the patients with a cross-sectional diameter under 10 millimetres.

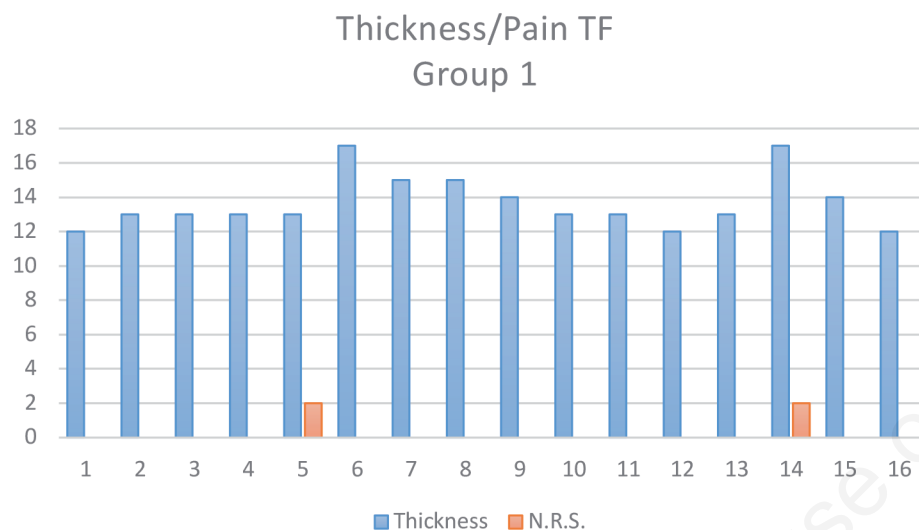


Figure 5. Thickness/Pain TF - Group 1.

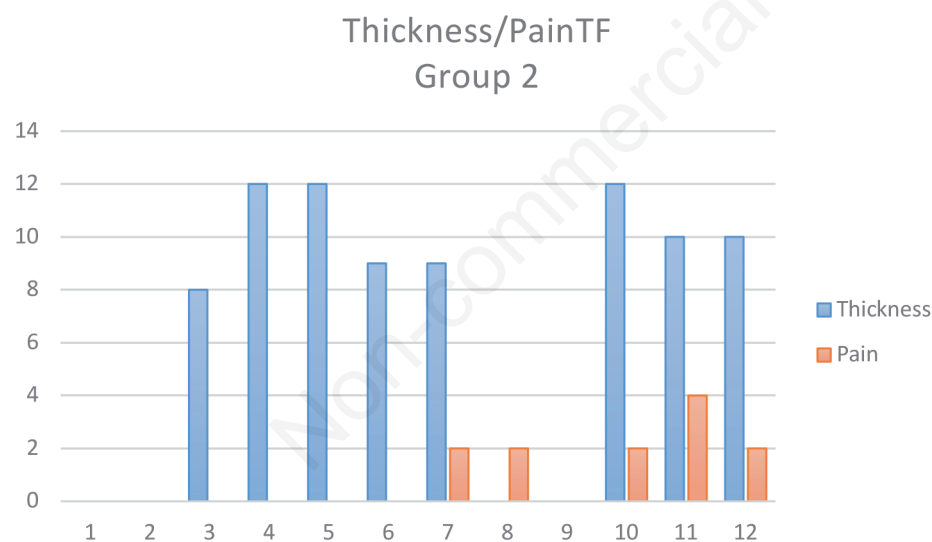


Figure 6. Thickness/Pain TF - Group 2.

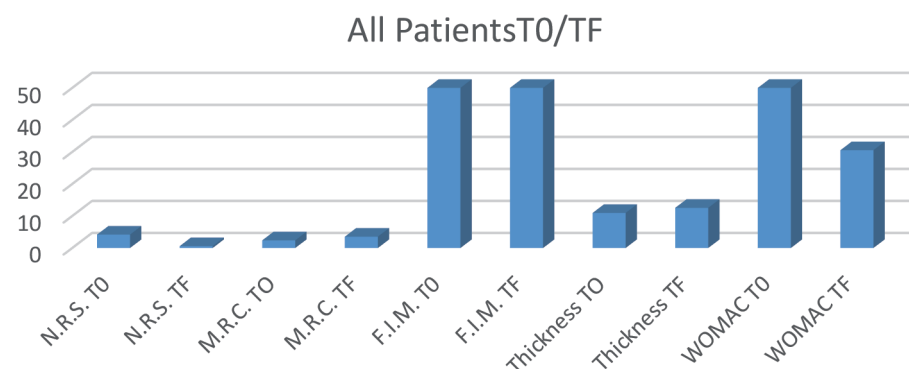


Figure 7. All patients T0/TF.

Furthermore, weakness of the vastus medialis after knee replacement may be an independent factor which influences the outcome in both males and females, regardless of age or comorbidities.

Finally, we noticed that it is possible to correlate strength and thickness of the vastus medialis using ultrasound, and that the results of this technique are reproducible, easy and inexpensive.

Conclusions

Osteoarthritis occurs when the cartilage of joints deteriorates. Often the result is a chronic pain and disability. Medical treatments or physiotherapy can reduce pain and improve quality of life. When these are ineffective, knee arthroplasty is an option.

The literature shows that a percentage of 20% patients after knee replacement is not satisfied and have evident limitations in performing activities and pain.³⁰ The cause for this outcome is still unclear and aetiology is multifactorial.

Our study demonstrates that vastus medialis could be involved in pain in the medial area of knee. Patients with a cross-sectional diameter under 0 millimetres show both more pain and disabilities at admission compared to patients with a diameter over 10 millimetres. These outcomes remain unchanged until discharge with worse results regarding in terms of pain and functional activities.

Furthermore, we saw from eco-ultrasonography that it is possible to evaluate the status of the muscle mass. Muscle thickness is an indicator of strength. Weakness could be an independent factor to evaluate the outcome in patients who undergo knee arthroplasty.

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