

Original paper

Clinical and Radiological Assessment of Quadriceps Atrophy after Acute Knee Joint Injury.

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Abstract

Background: knee injuries is common problem, immobilization of the knee during management of acute injury carry risk of muscle atrophy that have negative impact on regaining preinjury level of strength ⁽¹⁾.

Aim of study: To minimize the risk of quadriceps muscle atrophy after acute knee joint injury and to detect the early sign of muscle atrophy by using the specific imaging methods to restore the preinjury level of function for the patient when it possible.

Methods: prospective cohort study where data collected from outpatient clinic during the period of October 2017to October 2018. Patients selected with acute knee injury who presented within 24 hours, management protocol involved 7 days of immobilization then followed by 6 weeks of rehabilitation program for quadriceps strengthening, the evaluation of muscle wasting include clinical assessment of thigh circumferences and ultrasonography of muscle volume at three different points of time. Statistical analysis undertaken to determine any correlation between atrophy and other variables and the relation between clinical and radiological measurements using chi- square test to determine P. Value.

Results: 32 patients, 9 of them were females, with a mean age 29.8 year. The measurement shows significant atrophy after 7 days of immobilization with excellent impact on muscle strength after 6 weeks of rehabilitation when compared the injured with healthy side. Clinical assessment compared to radiological assessment of muscle atrophy. The comparison of the real thigh circumference and ultrasonography readings of the injured limb between the three measurement phases (day 1, day 7 and week 6 after injury) showed significant differences ($p < 0.001$).

Ultrasound measurement comparison of the thigh circumference reading of the injured limb between the three measurement phases (day 1, day 7 and week 6 after injury) showed no significant differences ($p = 0.439$).

Conclusion: Muscle atrophy can occur as early as one week of immobilization after knee injury. Where both clinical and radiological method can be used efficiently to assess muscle atrophy.

Key words: knee injury, thigh circumference, ultrasonography, atrophy, quadriceps, rehabilitation, immobilization.

Introduction

The knee is the most complex human joint, and majority of its injuries result from sport and traffic accidents or falls ⁽²⁾

After the diagnosis and principal management of trauma, the conservative or operative treatment and functional rehabilitation should be performed. During early period of management where immobilization is started, muscle atrophy occurred ⁽²⁾.

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This atrophy of muscle happened after limited, reduced mobility lasting few days followed by reduction of muscle cross section of load bearing thigh muscles ⁽¹⁾.

Muscle atrophy has been investigated by several experimental models to detect underlying mechanisms, where atrophic muscle is characterized by a catabolic metabolism ⁽¹⁾. The rate of protein synthesis is reduced and that of protein breakdown increased. Autophagic activities probably play an important role in early stages of muscular atrophy ⁽²⁾. The oxygen supply to disused muscle may be impaired, although myoglobin content is increased in atrophic muscle ⁽⁴⁾. The complete loss of mitochondrial function during the first days of disuse may be of etiological importance ⁽²⁾. The amount of connective tissue is increased in atrophic muscle and surrounding periarticular tissue which may lead into a vicious circle of musculoskeletal degeneration ⁽³⁾. An almost complete recovery from atrophy is possible, yet often the recovery phase is much longer than the total immobilization period ⁽⁴⁾. This study tries to determine the intensity and duration of the atrophy, the impact of rehabilitation on gaining of muscle size and function and how to restore the preinjury level of function for the patient when it possible. Evaluate the clinical assessment in relation to radiological assessment by ultrasonography of muscle atrophy is also determined.

Patients and Methods

Prospective cohort study was conducted from October 2017 to October 2018 at orthopedic outpatients' clinic at Imam al-Hussein medical city. Thirty-two patients (23 men, 9 women) at age 18-45 years (mean; 31.5 years) were involved in the study. Patients were suffered from acute knee injury

within 24 hours duration. They diagnosed with cartilage, meniscus injury and/or anterior cruciate ligament injury. Excluded criteria including; age more than 45 or less than 18 years old, chronic knee injury, delay presentation after 24 hours of injury, knee injury other than cartilage, meniscus or anterior cruciate ligament, patient preferred early surgical management, presence of mechanical problem like locking and frank instability, morbidly obese patients, and those previous treated with surgical intervention at knee or thigh.

Patient's evaluation started with detailed history dealing firstly with the mechanism of injuries, which varies including sport activities, traffic accidents and falls in the working places, home or in the street. Then, the assessment of the main presenting symptom, which was knee pain and its details.

Formal knee examination was done for all the patients, comparison with the contralateral normal side. On physical examination concentrate on thigh circumference and special test for ligaments and meniscus and all these data was recorded.

Radiological assessment includes plain radiograph for all the patients to exclude associated fracture or looking for others signs like Second fracture, further radiological assessment includes ultrasonography to measure the quadriceps volume which is vital part of the study, final radiological assessment was using MRI for confirming the diagnosis.

The patients were treated conservatively, with immobilization, for 7 days. During that period, rehabilitation started with leg elevation and cooling and with isometric exercises. After immobilization, all patients went to physical therapy for 6 weeks, which started with range of motion then isometric exercise then the

program included isotonic and isokinetic exercises. The program was implemented for each patient in order to maintain the muscle volume and joint mobility.

Protocol of measurements of quadriceps muscle

The patients were assessed three points of times:

- I. At the time of presentation (within 24 hours of the injury).
- II. After 7 days, when immobilization was finished.
- III. After 6 weeks when rehabilitation was completed.

The evaluation parameters of measurement

The volume of the quadriceps femoris muscle of the injured limb obtained by two methods:

- a. The clinical assessment by measuring of thigh circumferences by tape measure at distance of 15 cm above the patella.
- b. The radiological measurements were performed on the same ultrasound apparatus by using a linear probe of 7.5 MHz frequencies. During the measurements, the subjects were laying on their backs with stretched legs, with muscles relaxed and with their feet in a neutral position.

Both limbs including the normal side were examined.

Muscular volume was measured by horizontal and vertical scanning of the upper thigh, in the center of the upper thigh and 5 cm proximal and distal from the center. In their central segments, vastus intermedius muscle and rectus femoris muscle have square shapes.

The healthy contralateral leg was also assessed by the same methods for comparison.

Statistical Analysis

The computer program Statistical Package for Social Sciences version

(SPSS version 17) was used for the statistical data processing. General data regarding the subjects and measurements of the muscle volume were presented by the mean and standard deviation. The measurements were compared to determine significant difference in the mean using Student's t-tests. The p value below 0.05 was considered significant.

Result

Patients who had been completed the study protocol were 32 patients. Nine of them were females (The patient age ranged from 20-45-year-old with mean 29.8 year (± 5.34 year).

The injured limb was varying between the patients, which is most commonly. The left leg and the non-dominant one as (figure 2) show.

Regarding the type of injury, the meniscus was the mostly cause of knee injury in our patients in 69% where 45 % of these injuries were associate with ACL too as shown in (figure 3.)

The clinical assessment of thigh circumferences was observed wasting of muscle after one week of immobilization with improvement of the measurement after 6 week of rehabilitation as shown in (table 1); this table also reveals the difference in previously mention measurement of the healthy side at same period.

Where (figure 4) compares the clinical evaluation the mean of thigh circumferences between injured and healthy limb at the selected period.

At the same period of time the ultrasonic assessment of quadriceps volume, range and mean show in (table 2).

The comparison of ultrasonic measurement between injured and healthy limb show in (figure 5).

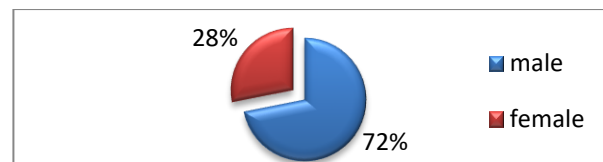


figure 1. The gender distribution of patients in the study

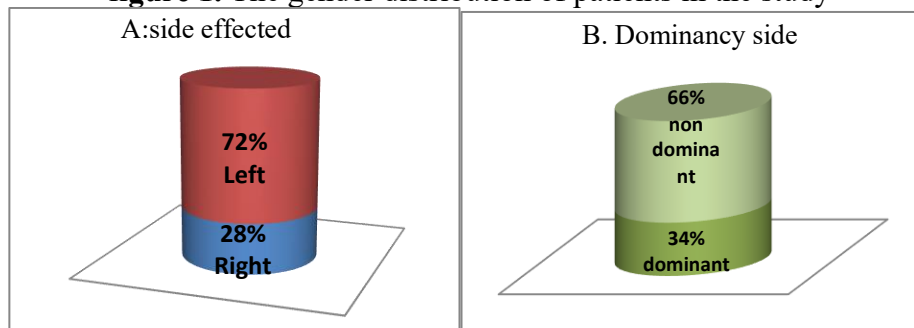


Figure 2. Affected side and dominance distribution in the study sample (n=32)

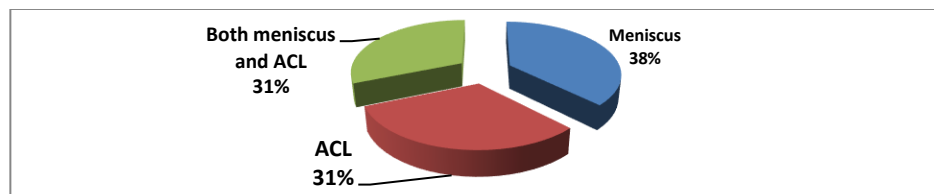


figure 3. The distribution of the type of injury among the study sample (n=32)

Table 1. The distribution of the range and mean tape circumference measurement of both injured and healthy limbs at presentation, after 7 day and at the end of rehabilitation at 6 weeks.

Time	at day1		at day 7		at 6 weeks	
Thigh circumference	Injured	Healthy	Injured	Healthy	Injured	Healthy
Range(cm)	53-57.2	53-57.2	51-55.2	53-57.1	52.5-56.8	53-57.2
Mean(cm)	55.17	55.16	53.42	55.03	54.69	55.13

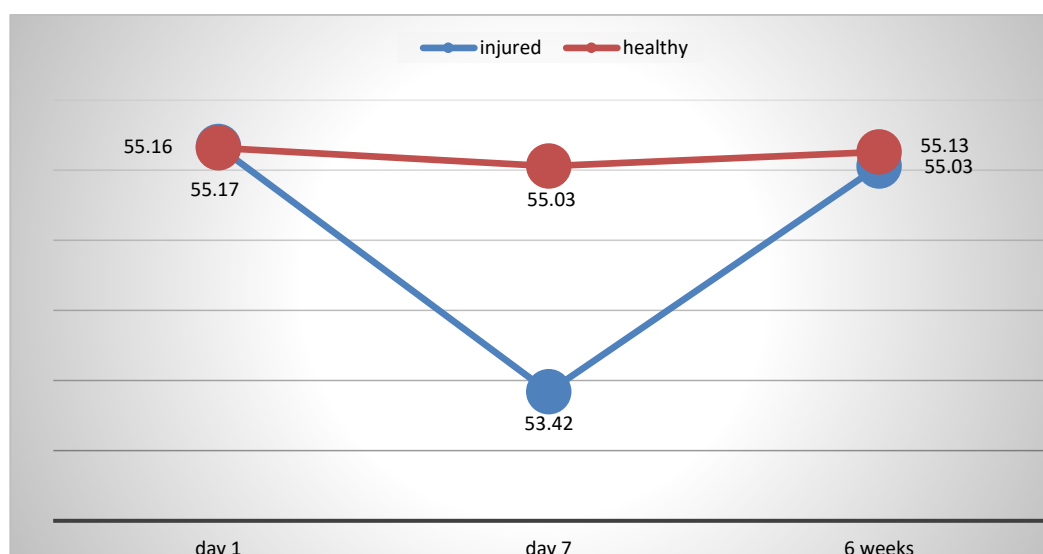
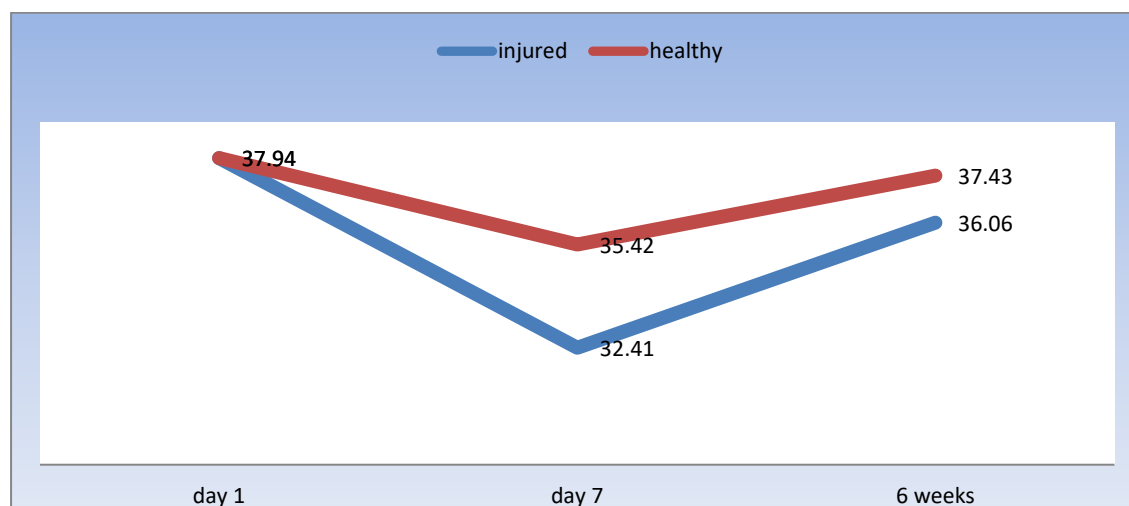


figure 4. Comparison between the thigh circumference at the three phases of measurement (n=32)

Table 2. The ultrasonic assessment of quadriceps volume range and mean at the three phases (n=32)

Measurement/ Phase	day1		day 7		6 week	
	Injured	Healthy	Injured	Healthy	Injured	Healthy
Range(mm3)	34.1-41.1	34.2-41	28.1-34.1	33.1-38.6	32.3-38	35.1-40.4
Mean(mm3)	37.94	37.94	32.41	35.42	36.06	37.43

**Figure 5.** The comparison between the mean quadriceps' circumference of the injured and normal limbs at the three phases of the study (n=32)**Data statistical analysis:**

The comparison of the real thigh circumference reading of the injured limb between the three measurement phases (day 1, day 7 and week 6 after injury) showed significant differences ($F(2,62) = 75.85$, $p < 0.001$). The mean thigh circumference readings at the three phases were 55.13cm, 53.47 cm and 54.57 cm, respectively.

Similarly, the comparison of the thigh circumference, Ultrasound measurement of the injured limb between the three measurement phases (day 1, day 7 and week 6 after injury) showed significant differences ($F(2,62) = 576.67$, $p < 0.001$). The mean thigh circumference readings at the three phases were 37.91cm, 32.47 cm and 36.00 cm, respectively.

When gender difference was determined, a significant gender difference was observed for both real circumference comparison of the thigh circumference reading of the injured limb between the three measurement

phases (day 1, day 7 and week 6 after injury) showed significant differences ($F(1,31) = 4.95$, $p = 0.034$).

When right and left sided limbs difference was determined, no significant side difference was observed for both real circumference comparison of the thigh circumference reading of the injured limb between the three measurement phases (day 1, day 7 and week 6 after injury) ($F(1,60) = 0.56$, $p = 0.458$).

Ultrasound measurement comparison of the thigh circumference reading of the injured limb between the three measurement phases (day 1, day 7 and week 6 after injury) showed no significant differences ($F(1, 60) = 0.62$, $p = 0.439$).

When dominance difference was determined, no significant difference was observed for both real circumference comparison of the thigh circumference reading of the injured limb between the three measurement

phases (day 1, day 7 and week 6 after injury) ($F(1,60)=0.19$, $p=0.664$).

Ultrasound comparison of the thigh circumference reading of the injured limb between the three measurement phases (day 1, day 7 and week 6 after injury) showed no significant differences ($F(1, 60)=0.829$, $p=0.370$).

Discussion

Many patients with knee injury prefer non operative management when it is possible to get rid complications of surgery, this type of management also carry problems specially when associated with immobilization and limited mobilization, that are led to negative adaptations of human body, like elevated risk for thrombosis, reduced fitness level and muscle atrophy⁽¹⁾

Loss of muscle strength is the most evident response to atrophy. Muscle strength decreases most dramatically during the first week of immobilization; little further weakening occurs later on. This is reflected in changes in the EMG of disused muscles and can also be observed in muscle weight and size of muscle fibers⁽²⁾

We started the management protocol with 1 week of immobilization to control the early patient symptom of injury and to prepare the patient for next step when the patient condition permit rehabilitation. we avoid immobilization more than week because prolong immobilization of the knee is an important factor in the development of thigh muscle atrophy and should therefore be diminished as much as possible⁽³⁾. Cruz-Martínez et al⁴ suggest that decrement in activated motor units may be the cause of the disproportionate weakness of the quadriceps muscle on the first days after immobilization by the plaster cast. The recovery of muscle fiber

conduction velocity was related with functional improvement of strength after the first week.

In the second week we start rehabilitation that address activation deficits as well as atrophy may be necessary to restore quadriceps strength⁽⁵⁾. Brasileiro et al⁽⁶⁾ found that eccentric training proved to be a potent resource for the quadriceps recovery, both morphologically and functionally, also he concludes that the contributions of functional and morphological factors varied according to the length of training.

The 6 weeks of rehabilitation is important because the majority of studies do not show significant gains in muscular trophism in the initial phases of training. Hortobágyi et al.⁷ observed that the initial adaptations to resistance training are almost exclusively neural. MacDougall et al.⁽⁸⁾ found increases in muscle strength before any measurable sign of hypertrophy could be observed.

Cruz-Martínez et al⁴ conclude that invasive muscle fiber conduction velocity was significantly slowed and showed a gradual improvement, reaching normal values after 6 weeks, while Enoka⁽⁹⁾ suggests that significant increases in cross-sectional area were not apparent before the eighth weeks of training.

Most of the patients in our sample were male that explained by the males were engage more than female in sport, military and heavy work not like females who were less interested in sport activities in our society.

The commonest side of injury was left nondominant side where anterior cruciate injury is more common in nondominant side. these variables were be found insignificant statistically regarding the wasting and regaining of muscle size.

The study protocol depending on evaluation and comparism of both side the injured and the healthy side and the

result of our study show that even the healthy side can be affected by immobilization but to lesser degree than the injured knee.

Terese et al ⁽¹⁰⁾ who found that the incidence of voluntary quadriceps inhibition on the involved side was three times that of uninjured, active young subjects, but the magnitude was not large.

The observation of result also show there was significant gender difference this also concluded by Nobuo et al¹¹ in his study where immobilization-induced loss of specific strength at isometric and slower angular velocity concentric contractions is attenuated in men compared with women. This sex-specific voluntary strength loss occurred despite a similar amount of muscle atrophy at the fiber and whole muscle level, with no fiber-type transitions after only 14 days of unilateral lower leg immobilization, while Arvidsson et al¹² conclude that females reacted more favorably than males to electrical stimulation of quadriceps during an immobilization period after knee surgery.

The atrophy of muscle occurred as early as one week and the effect of immobilization occur in both side which is clinically and statically significant in injured side but it is of no statistically significant in the healthy side as the result show.

Even with rehabilitation program, we observed that the injured knee did not restore the preinjury level of thigh circumferences and muscle volume which may be due to inadequate period of rehabilitation or may be due to poor compliance of patients on rehabilitation program,

We use ultrasonography in our study where There is limited number of studies about ultrasonographic estimation of muscular volume ⁽¹³⁻¹⁵⁾. The study from the Liverpool University measured the volume of the

muscle quadriceps femoris by magnetic resonance and at the same time by statistic B model of ultrasound ¹⁶. The differences obtained by these two methods were not significant. This fact proves that the ultrasound method is precise enough and appropriate for research in this area. In the study from Fornage et al.⁽¹⁷⁾, ultrasonography was performed to assess muscle injuries in 120 advanced-level athletes. It was shown as a reliable, useful method to locate and evaluate traumatic muscular lesions.

Mourtzakis et al ⁽¹⁸⁾ summarise his study about ultrasound that give the precision, practicality, and ease of use, and it is emerging as a highly useful tool in expediently measuring the muscle mass and changes in muscle tissue at the bedside. Ultrasound may be valuable in identifying patients who are at risk of malnutrition, in tracking muscle atrophy for the purpose of calculating nutrient delivery, and in assessing the success or failure of nutrition, pharmacological and rehabilitative interventions that aim to counter muscle atrophy ¹⁸.

The ultrasound measurement of muscular volume alteration is simple and acceptable method in every day practice, which enables monitoring of the response to the applied physical therapy ⁽¹⁹⁾.

Uremovic et al ⁽¹⁹⁾ study result show that ultrasonography should be conducted longitudinally, indifferent intervals, in order to assess the muscular atrophy as a result of immobilization inactivity, and later, the volume restitution as a result of rehabilitation. The results showed non-linear changes of volume in the time unit, either in atrophy or volume restitution. Furthermore, the vastus intermedius muscle recovered and reacted more slowly to the physical therapy than the rectus femoris muscle. Thus, the rehabilitation program, after knee injury, should be adapted to each

patient in order to increase the strength of each upper-leg muscle. These result correlate with the result of our study regarding use of U/S in determine quadriceps atrophy.

The data show there is excellent correlation of clinical measurement of thigh circumferences and radiological assessment of muscle volume in all phases of management which mean both method can be used reliably in determine muscle atrophy, although clinical assessment of thigh circumferences measurement reflect all thigh muscle bulk as well as bone and subcutaneous tissue, but the main bulk is from quadriceps muscle and its widely used and routinely performed.

Finally, it is important to remember that Morphological studies have demonstrated little relationship between amount of atrophy and weakness⁽²⁰⁻²¹⁾.

The study by Toran et al⁽²²⁾ findings suggest that quadriceps and hamstring muscle function, rather than muscle size, may be an important factor in the varied response early after ACL injury. Although Thomaset al⁽²³⁾ in his study found Quadriceps cross sectional area was strongly related to muscle strength six months after anterior cruciate ligament reconstruction and substantial injured versus uninjured limb deficits were demonstrated for strength and cross-sectional area.

Conclusion

1. Muscle atrophy can occur as early as one week of immobilization after knee injury.
2. Programmed rehabilitation is important to regain preinjury level.
3. Healthy side can be affected by immobilization to little amount which is insignificant
4. Both clinical and radiological method can be used efficiently to assess muscle atrophy.

5. The correlation between muscle volume and muscle power not always linear.

Recommendation

1. Immobilization should be minimized after knee injury,
2. Rehabilitation program should be as soon as possible to prevent muscle atrophy.
3. Clinical assessment of quadriceps atrophy is recommended as reliable method.

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