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Ultrasound Measurement of the Volume of Musculus Quadriceps after Knee Joint Injury

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A B S T R A C T

The monitoring of the recovery of femoral muscles, after the knee-joint injury, is possible by the method of ultrasound measurement of the muscular volume. In a clearly defined longitudinal study, our object was to standardize the method of ultrasound measurement of muscular volume and to evaluate its adequacy in practical application in quadriceps muscle rehabilitation. The ultrasound measurements of m. rectus femoris and m. vastus intermedius were conducted in three intervals: in the first 24 hours after the injury; after 1 week, when immobilization was removed; and after 6 weeks, when rehabilitation was finished. The study comprised 30 patients with knee-joint injury, and 30 asymptomatic subjects, who formed the control group. The results showed significant decrease of muscular volume (mm^3) after joint immobilization on injured leg and a significant increase of volume after rehabilitation. The same differences were observed on healthy legs, but without significance. Within the same intervals, there were no changes in the muscular mass in the control group. M. rectus femoris was completely recovered in greater number of patients (54.1%), comparing to m. vastus intermedius (25.4%). We conclude that the ultrasound is an appropriate method for monitoring the process of muscular atrophy during immobilization, as well as the course of muscular restitution during the physical therapy.

Key words: *ultrasound measurements, muscular volume, muscular atrophy, knee joint injury, rehabilitation*

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Introduction

The knee is the most complex human joint, and majority of its injuries result from sport and traffic accidents and falls. After the diagnosis and principal management of trauma, the conservative or operative treatment and functional rehabilitation should be performed[1]. Rehabilitation should start early in order to prevent secondary damages, like connective tissue fibrosis and muscular atrophy and to improve the results of rehabilitation[2]. Until recently, the rehabilitation of upper-leg muscles was monitored by measuring the extent of muscles, using the centimeter tape. But that method is indirect, because measurements cover all parts of the upper leg (bone, fat tissue and skin thickness). Ultrasound, computed tomography or magnetic resonance, are methods for precise and accurate measurement of the change of quadriceps muscle volume during rehabilitation[9–13]. The advantages of ultrasound are the lack of ionizing radiation and its inexpensiveness[14,15]. It enables the records in the »real time« and can be repeated with no harm for the injured person.

Even though the number of knee joint injuries has increased in the recent time, the studies on monitoring the recovery of quadriceps muscle after injury, using ultrasound, are extremely rare. Every injury of the knee results in the development of atrophy of the upper leg muscles and successful rehabilitation of the injury includes also the regression of the normal tonus and volume of surrounding muscles. In this study, we measured the changes of quadriceps muscle volume, during the periods of joint immobilization and rehabilitation, in patients who had experienced the knee injury. The specific aims of this follow-up study were:

- to measure objectively, with ultrasound, the extent of atrophy of quadriceps muscle during immobilization and its recovery during and after immobilization;
- to assess the validity of ultrasound method in monitoring the changes in quadriceps muscle volume, in the routine clinical practice.

Subjects and Methods

Subjects

The investigation comprised 30 patients (21 men, 9 women), aged 36.7+10.3 years, who were hospitalized in Trauma Clinic Center in Zagreb, for the following diagnosis: acute menisci disruption, extension of the external lateral or anterior crucial ligaments. The diagnoses were based on radiological, ultrasound and clinical examination. The causes of injuries were sport activities, traffic accidents and falls at the working places, home or in the street.

All patients were treated conservatively, with gypsum or dynamic 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 included isotonic and isokinetic exercises. The program was created for each patient in order to maintain the muscle volume and joint mobility and, occasionally, it included magnetic therapy and electro stimulation of the femoral muscle.

The control group consisted of 30 subjects of the same age, who had no history of knee injury and had never actively participated in sport activities.

Protocol

All measurements in patients and controls were performed three times: in the period less than 24 hours after the injury; after 7 days, when immobilization was finished; and after 6 weeks when rehabilitation was completed. The evaluat-

ing parameter was the volume of the musculus vastus intermedius and musculus rectus femoris of the injured and healthy leg, obtained by the ultrasound. The measurements were performed on the ultrasound machine Kranzbüchler, Medizinische systeme GMBH, Germany, 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 legs were examined in patients and controls.

Muscular volume was measured by horizontal and vertical scanning of the upper leg, in the center of the upper leg and 5 cm proximal and distal from the center. In their central segments, m. vastus intermedius and m. rectus femoris have square shapes. Therefore, the formula for measuring the volume of the central muscular segment was: $V = a \times b \times c$ (a = the length of the upper leg, b = the probe width, c = the average muscular width obtained by longitudinal and transversal scanning for six times, in the center and 5 cm proximal and distal form the center).

The ultrasound performed one examiner (the author of the study). Reproducibility of the ultrasound method was determined by measuring repeatedly 10 healthy volunteers during one day, because one cannot expect the change in muscle volume in such a short period. The error of this method has been estimated from the differences and the coefficients of variability of these measurements. The calculated measurement error was below 2%.

Anthropometric measurements were performed once and included body height and weight.

Statistics

The computer program SPS (SPSS – 7.5 for Windows, SPSS inc., Chicago, USA) was used for the statistic 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 with Student's t-tests. The p value below 0.05 was considered significant.

Results

The general data for patients and controls are presented in Table 1. There were no significant differences between them in age, height and weight. There was also no significant difference between the number of injuries on the right and left knees.

TABLE 1
GENERAL DATA OF PATIENTS AND CONTROLS

	Patients (N=30)	Controls (N=30)
Age (years)	30.6 ± 10.3	30.2 ± 6.9
Weight (kg)	74.6 + 12.8	71.0 ± 8.5
Height (cm)	173.0 ± 6.8	172.5 ± 6.2

Tables 2 and 3 show changes of volumes of m. rectus femoris and m. vastus medialis in patients and controls, determined by ultrasound. In the second measurements, after immobilization, the volumes of both muscles in the injured leg were significantly lower comparing to the first measurement ($p<0.001$). In the third measurement, after rehabilitation, those volumes became significantly higher than in the second measurement ($p<0.01$). The volumes of both muscles in the healthy patient's legs also decreased after one week and increased after six weeks, but those differences were not significant.

In the first measurements, after injury, there were no significant differences between volumes of the injured and healthy legs of patients. But those differences be-

TABLE 2
ULTRASOUND MEASUREMENTS OF VOLUME OF M. RECTUS FEMORIS IN PATIENTS AND CONTROLS IN DIFFERENT TIME INTERVALS. DIFFERENCES ARE TESTED BY T-TEST

	M. rectus femoris volume (mm^3)		
	24 hours	7 days	6 weeks
Patients			
Injured leg	17,602 ± 4,112[a]	13,953 ± 2,812[a,b,c]	15,688 ± 3,487[d]
Healthy leg	18,195 ± 3,914	17,258 ± 3,719	18,252 ± 3,686
Controls			
Ipsilateral leg	16,840 ± 4,474	16,897 ± 4,534	16,910 ± 4,533

[a] p<0.001: differences between subsequent measurements
[b] p<0.01: differences between patients and controls in the same time interval
[c] p<0.001, [d] p<0.01: differences between injured and healthy leg of patients, in the same time interval

TABLE 3
ULTRASOUND MEASUREMENTS OF VOLUME OF M. VASTUS INTERMEDIUS IN PATIENTS AND CONTROLS IN DIFFERENT TIME INTERVALS. DIFFERENCES ARE TESTED BY T-TEST

	M. vastus intermedius volume (mm^3)		
	24 hours	7 days	6 weeks
Patients			
Injured leg	16,449 ± 2,974[a]	13,234 ± 2,736[a,b,d]	14,936 ± 2,555[c,e]
Healthy leg	18,114 ± 4,007	16,962 ± 3,192	17,986 ± 3,144
Controls			
Ipsilateral leg	16,951 ± 4,404	17,025 ± 4,441	17,039 ± 4,448

[a] p<0.001: differences between subsequent measurements
[b] p<0.001, [c] p<0.05: differences between patients and controls, in the same time interval
[d] p<0.0001, [e] p<0.001: differences between injured and healthy leg of patients, in the same time interval

came significant for both muscles in the second measurement (p<0.001 for m. rectus femoris; p<0.01 for m. vastus intermedius) and in the third measurement (p<0.01 for m. rectus femoris; p<0.001 for m. vastus intermedius).

The volumes of muscles in the control group were similar in all measurements. Differences between patients and controls were tested between injured legs and healthy legs of the controls of the same side. The volume of both muscles was significantly lower in patients comparing to controls in the second measurement (p<0.01 for m. rectus femoris; p< 0.001 for m. vastus intermedius) and for m. vastus intermedius in the third measurement (p<0.05).

Table 4 shows the tight girth in patients and controls, obtained at the time of ultrasound measurement. The girth in injured legs declined after 7 days and increased after rehabilitation, although the differences were not significant. The values of measurement were similar in controls and in healthy legs of patients, in all time intervals.

TABLE 4
TIGHT GIRTH IN PATIENTS AND CONTROLS IN DIFFERENT TIME INTERVALS

	Tight girth (cm)		
	24 hours	7 days	6 weeks
Patients			
Injured leg	53.2 + 4.1[a]	51.8 + 4.1[a]	52.5 + 4.1
Healthy leg	53.2 + 4.0	53.0 + 4.1	53.3 + 4.0
Controls			
Ipsilateral leg	52.1 + 3.1	52.1 + 3.1	52.1 + 3.1

[a] $p<0.05$: differences between subsequent measurements

Full recovery of the rectus femoris muscle was achieved in more than a half of the patients, i.e. 54.1% (Figure 1). Vastus intermedius muscle responded less readily to physical therapy. Full recovery was achieved in 25.4% of patients ($p< 0.05$).

Discussion

The results of this study showed significant differences in the muscular volumes, obtained by ultrasound, during the immobilization and rehabilitation of patients with knee injury.

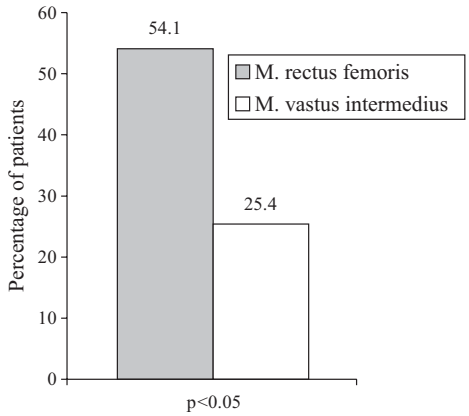

Fig. 1. Percentage of patients with complete recovery of m. rectus femoris and m. vastus intermedius.

It is known that muscular volume is changed by age in humans[16]. Inactivity and immobilization is necessary after a joint injury. The lack of muscular contraction results in atrophy of the injured muscles. On the other side, successful rehabilitation of the joint should regain a normal tonus of the upper leg musculature. 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. In this study, we simplified as much as possible that method, in order to use it in regular routine clinical work.

There is limited number of studies about ultrasonographic estimation of muscular volume[17–19]. The study from the Liverpool University measured the volume of the m. quadriceps femoris by magnetic resonance and at the same time by statistic B model of ultrasound[20]. 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.[21], 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.

To our knowledge, there is no investigation where the volume of the m. quadriceps femoris was monitored with ultrasound, after knee joint injury. Our measurements were conducted longitudinally, in different 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, m. vastus intermedius recovered and reacted more slowly to the physical therapy than m. rectus femoris. Thus the rehabilitation program, after knee injury, should be adapted to each patient in order to increase the strength of each upper-leg muscle.

We conclude that the ultrasound is simple and appropriate method for monitoring the rehabilitation of muscles of the injured patients. However, practical application of ultrasound measurements is not simple, because it requires experience and procedure standardization.

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ULTRAZVUČNO MJERENJE VOLUMENA NATKOLJENIČNOG MIŠIĆA NAKON OZLJEDE KOLJENSKOG ZGLOBA

S A Ž E T A K

Ultrazvučnim mjerenjem mišićnog volumena može se pratiti oporavak natkoljeničnog mišića, nakon ozljede koljenskog zgloba. Cilj ovog istraživanja je bila procjena metode ultrazvučnog određivanja mišićnog volumena kod rehabilitacije m. quadricepsa. Mjerenja su učinjena na m. rectus femoris i m. vastus intermedius, u tri navrata: unutar 24 sata nakon ozljede koljena; nakon imobilizacije (1 tjedan); i nakon rehabilitacije (6 tjedana). Sudjelovalo je 30 bolesnika s ozljedom koljena i 30 zdravih ispitanika. Nađeno je značajno smanjenje mišićnih volumena (mm^3) ozljeđene noge, nakon završetka imobilizacije i značajan porast mišićnog volumena nakon rehabilitacije. U kontrolnoj skupini nije nađena promjena mišićne mase. Potpuni oporavak m. rectus femoris je postignut u 54.1% bolesnika, a m. vastus intermedius u 25.4% bolesnika. Zaključujemo da je ultrazvuk prikladna metoda za praćenje mišićne atrofije za vrijeme imobilizacije zgloba, kao i mišićnog oporavka nakon rehabilitacije.