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Quadriceps femoris muscle function prior and after total knee arthroplasty in women with knee osteoarthritis

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Abstract
Purpose The aim of the present study was to evaluate an isometric voluntary force generation and relaxation capacity of the quadriceps femoris (QF) muscle prior and after total knee arthroplasty (TKA).
Methods Isometric maximal voluntary contraction force, rate of force development, voluntary activation, half-relaxation time, and latency of contraction of the QF muscle were recorded in 12 female patients (aged 49–68 years) with knee osteoarthritis one day before, 3 and 6 months following TKA in the operated and nonoperated leg. Knee pain intensity was assessed by visual analog scale, and Knee injury and Osteoarthritis Outcome Score (KOOS) questionnaire was used to assess knee problems during daily living.
Results A significant decrease in knee pain and significant increase in KOOS were established after TKA. Maximal voluntary isometric force in the operated leg was lower ($P < 0.05$) before, 3 and 6 months after TKA as compared to the nonoperated leg. Rate of force development of the QF muscle in the operated leg compared to the nonoperated leg was significantly lower ($P < 0.05$) 3 and 6 months after TKA. Voluntary activation, latency of contraction, and half-relaxation time of the QF muscle did not differ significantly before, 3 and 6 months after TKA.
Conclusions The present study indicated reduced maximal and explosive strength of quadriceps femoris muscle in the operated leg 3 and 6 months after TKA with no significant changes in voluntary activation, and capacity for rapid contraction and relaxation.
Level of evidence Prospective comparative study, Level II.

Keywords Isometric muscle contraction · Muscle relaxation · Knee osteoarthritis · Total knee arthroplasty · Muscle exercises

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Introduction

Knee osteoarthritis (OA) is a degenerative and chronic joint disease characterized by a loss of joint cartilage tissue, subchondral cysts, meniscal tears, edema, degenerative changes of the capsular ligamentous supporting structures, and osteophyte formation [5]. Osteoarthritis of the knee is also strongly associated with weakness of quadriceps femoris (QF) muscle [13, 19]. Although several treatment options are available, total knee replacement is the end-stage treatment of knee arthritis [4]. Despite positive outcomes associated with total knee arthroplasty (TKA), which reduce pain and improve the functional properties, full recovery of the muscle strength and physical function to a normal level is rare [16, 37]. Many studies have confirmed that weakness of the QF muscle persists even years after surgery [20, 30, 33, 37].

Quadriceps femoris muscle strength and function after TKA are a complex multifactorial issue [10]. The assessment of voluntary force production and relaxation capacity of QF muscle is an important outcome in the measurement of musculoskeletal disorders [14, 16, 19, 35]. A recent study has focused on muscle force generation during patellar tendon reflex reaction [6]. Despite the fact that there are many studies about QF muscle strength [1, 4, 16, 24], the understanding of muscle dysfunction in OA knees still remains speculative [6]. It is unclear that why muscle strength does not recover after TKA and how extensive is the lack of central drive to the muscle during contraction.

A muscle contraction requires both the central and peripheral activation process. The failure of central activation may reduce the force output of a muscle or not recruit all motor units during maximal voluntary contraction (MVC) [23, 31]. Neuromuscular dysfunction may have serious consequences on the articular function [13]. The extent of central activation is rarely taken into consideration when assessing maximal muscle force. Changes occurring in periarticular muscles and the nerves controlling them have also received less attention [13]. It is difficult to ascertain whether postexercise reduction in force represents structural damage to the muscle or is simply a reduction in voluntary drive [23]. Insufficient attention has been paid to investigating the capacity of relaxation of the QF muscle in patients with knee OA, which is also an important indicator of neuromuscular performance and movement control.

In order to function normally, a muscle needs to be strong, nonfatigued, under accurate motor control and have a good sensory mechanism [13]. After voluntary activation improvement, physical therapy should target the augmentation of QF muscle strength [3]. The adequate rehabilitation of patients with knee OA has to include a variety of exercises to address motor [27] and sensory deficits [15]. Exercises should improve muscle strength and endurance, control of movement, balance and coordination, and it is also important that exercises could be converted into functional performance by practicing common activities of daily living [13]. Group exercises and home exercises are equally effective and considered important by patient preference [27].

The aim of this study was to assess isometric maximal and explosive strength, voluntary activation, and capacity of rapid voluntary contraction and relaxation of the QF muscle prior, 3 and 6 months following TKA. The second objective was to assess the effect of postsurgery home exercises for these characteristics. The research hypothesis was that deficits occur in the QF muscle function characteristics described in knee OA patients before the operation and 6 months following TKA.

Materials and methods

Twelve women with degenerative knee OA in stage III or IV according to the Kellgren–Lawrence Scale, who underwent unilateral TKA, were recruited and assessed one day before, 3 and 6 months after knee surgery. Six subjects also had a diagnosis of knee OA in the contralateral leg, but the disease was in the first stage according to the Kellgren–Lawrence Scale. The patients' mean age was 61 years (SD 6.8 years, range 49–68 years) and the mean body mass index 33 kg/cm^2 (SD 4.6 kg/cm^2, range 25–41 kg/cm^2). The subjects were initially selected from surgical waiting lists. The inclusion criteria of the study were the diagnosis of primary knee OA, the first TKA, and the ability to walk without aid. The exclusion criteria were significant cardiovascular or pulmonal disease, neuromuscular disease, and any other joint replacement of lower limb. The average period of knee OA symptoms before operation was 6 years. The assumed causes of knee OA of the patients in the current study were heavy physical work (6) and prior trauma (6). Before participation in the study, all patients gave a written informed consent. The study received the approval of the Ethics Committee of the University of Tartu.

Knee surgery

Total knee arthroplasty is the end-stage treatment for knee arthritis. In surgery, an anterior linear incision for deeper tissues with the detachment of the musculus vastus medialis from the patella was performed. The patella was displaced aside of the joint, which disclosed the distal end of femur and the proximal end of tibia. Inflamed and damaged joint tissues were removed. In all cases, the condylar endoprosthesis GEMINI (W. Link Gmbh and Co., Germany) with rotating plateau was used because of moderate knee varus deformity (up to 10°) and stable knee ligaments. In all cases, endoprosthesis components were fixed onto the bone with cementation. Using GEMINI prosthesis, the posterior cruciate ligament was preserved. During the operation, any knee deformities were corrected and the ligaments were balanced.

Postoperative rehabilitation

The average period of hospital stay was 5 days. Postoperative rehabilitation began on the 1 day after surgery with knee mobilization and isometric exercises for strengthening thigh muscles. In addition to supervised physiotherapy, all patients trained the operated leg's mobility with continuous passive motion device. The physiotherapist of orthopaedics department instructed the patients how to transfer themselves into and out of bed, how to walk with crutches on level ground and stairs, and how to allow the weight bearing to the operated leg. Each subject received a detailed supporting handout containing instructions and photographs of the exercises to be performed at home. The handout included range of motion exercises, strengthening and stretching exercises [7], movement control, balance and coordination exercises [13]. In addition, walking, cycling, and swimming were recommended. All subjects filled in a training diary with the number of exercises from the handout, the number of repetitions and series, and comments in free form (e.g., cycling for 25 min). The study's author made phone calls to the patients monthly to check on the subjects' recovery and make sure they performed the exercises. Additionally, during the 3 and 6 month examination, the subjects received counseling and encouragement to continue specific exercises and physical activity. Walking without crutches and with full weight bearing was allowed about one and a half-month after TKA or when walking was secure and painless.

Clinical assessment

Each patient was interviewed pre and postoperatively for the severity of knee pain, and Knee injury and Osteoarthritis Outcome Score (KOOS) was calculated. Knee pain was assessed by visual analog scale (VAS) in points ranging from 0 (no pain) to 10 (unbearable pain). KOOS is a 42-item self-administered self-explanatory questionnaire covering five patient-relevant dimensions: Pain, Other Disease-Specific Symptoms, ADL Function, Sport and Recreation Function, and knee-related Quality of Life [28]. The five patient-relevant dimensions of KOOS were scored by a specific formula separately. The scores were transformed to a 0–100 scale, zero representing extreme knee problems and 100 representing no knee problems.

Measurements of QF muscle function

Voluntary isometric force generation and relaxation characteristics

During isometric QF muscle test, the subjects sat in a custom-made dynamometric chair equipped with a chair-fixed standard calibrated strain-gauge transducer DST 1778 (Russia) connected with the plate by a rigid bar (knees and hips at 90 and 110°, respectively) [9]. Velcro belts placed over the shoulders and pelvis secured the subject's body position. The strain-gauge transducer pad was placed approximately 3 cm above the apex of the lateral malleolus on the anterior aspect of the leg. Signals from the strain-gauge transducer were linear from 0 to 2,500 N. The force signals were sampled at the frequency of 1 kHz and stored on computer hard disk, using WsportLab software (Urania, Estonia). During the testing of QF muscle isometric MVC force, the subjects were asked to produce maximal force (approx. 3 s) with exertion of knee extension against the cuff of the strain-gauge system [9]. From three maximum attempts, the highest force value was taken for further calculation. The strong verbal encouragement was used to motivate the participants.

To determine the capacity for rapid voluntary isometric contraction and relaxation of the QF muscle, the subjects were instructed to react to the signal lamp quickly and forcefully by extending the leg against a cuff fixed to a strain-gauge system. The maximal effort was maintained as long as the signal lamp was on (approx. 2 s), and the muscles were relaxed quickly after the signal lamp was off. The following characteristics were calculated: latency of contraction (LATc)—the time delay between the visual signal and the onset of force production—rate of isometric force development (RFD_{50})—the first derivate of force development (dF/dt) at the level of 50% of MVC—and half-relaxation time (HRT)—the time of half of the decline in force during relaxation [33].

The reproducibility of the torque measurements was assessed with repeated static load on the strain-gauge transducer. The relative error between trials and the relative difference was less than 0.5%. The high reliability of maximal isometric strength measurements using the chair-fixed dynamometer and test–retest correlations with a 5-day interval between measurements ($r = 0.92$) has been demonstrated in an earlier study [26].

Voluntary activation

Electrical stimulation allows assessing the activation process of peripheral part of the neuromuscular system. During the testing of voluntary activation (VA) of the QF muscle, the transcutaneous electrical stimulation with supramaximal square wave pulses (100% MVC) of 1 ms duration was applied using an isolated voltage stimulator (Medicor MG-440, Hungary) and two self-adhesive surface electrodes (5 × 10 cm, Medicompex SA, Switzerland) placed on the groin (anode) and proximal (cathode) third of the thigh. Electrical stimulation was applied through femoral nerve. Twitch-interpolated technique was used to estimate VA of the QF muscle [9, 14]. The subjects were asked to reach their maximal force level during 3 s (the total duration of contraction was approximately 5 s) and to maintain it after the supramaximal stimulus was delivered and until they were asked to relax. Visual feedback was provided by the display of strain-gauge amplifier. When the subject's QF muscle was completely activated, additional force was generated by superimposed twitches. Additional force produces extra activity for incompletely activated motor units during the stimulus. Figure 1 provides an

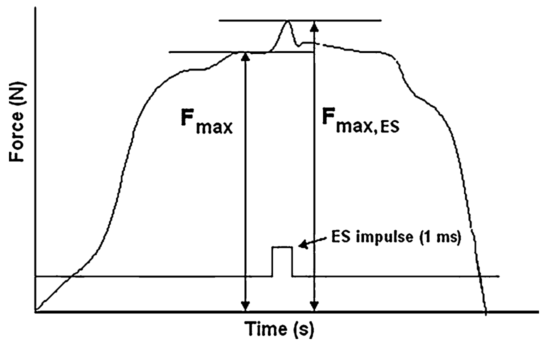

Fig. 1 A typical force–time curve obtained during the assessment of voluntary activation of the quadriceps femoris muscle. Fmax—isometric force before electrical stimulation—Fmax,ES—force developed during electrical stimulation

example of the typical voluntary activation force determination diagram. The intensity of stimulus was assessed first to avoid the effect of twitch potentiation caused by prior contractions [9]. The subjects performed three trials with the interval of 2 min, and the trial with the greatest prestimulus voluntary force was taken for further analysis. The highest mean prestimulus force (MVC force) (F_V) and maximal poststimulus force (F_{ES}) were used to calculate voluntary activation of the QF muscle by the formula: $VA = (F_V : F_{ES})\ 100(\%)$. The $VA \geq 95\%$ was used as the definition of full activation of the QF muscle [7, 17].

Experimental protocol

The women with knee OA were examined 1 day before, 3 and 6 months after TKA in the Laboratory of Kinesiology and Biomechanics. The subjects were asked about their knee pain severity, the KOOS questionnaire was fulfilled, and the assessment of the QF muscle function was performed. Before muscle testing, the subjects performed a warm-up with exercise bike during 5 min. At first was determined the MVC force of the QF, followed by a signal lamp test, which allowed to calculate the capacity for rapid voluntary contraction and relaxation. After five-minute rest period, VA of the QF muscle was recorded. In all trials, 3 attempts were performed with two-minute recovery time. In subjects, the nonoperated leg was tested initially, thereafter the operated leg.

Statistical analysis

All data are presented as means and standard error of mean (±SE) with probability values of <0.05 to indicate statistical significance. One-way analysis of variance (ANOVA) followed by Bonferroni post hoc comparisons was used to evaluate differences between the operated and nonoperated leg. A paired t-test was used to evaluate differences between pre and postoperative characteristics. Statistical power analysis demonstrated that twelve patients were sufficient to detect a significant difference (alpha = 0.05) in the operated leg's MVC force before and 3 months after TKA (power > 0.96) and before and 6 months after TKA (power > 0.76). Statistical power of the operated leg's RFD_{50} and LAT_C was before and 6 months after TKA in both cases 0.96. Statistically significant difference was set at alpha level 0.05.

Results

Preoperatively, knee pain in the operative leg evaluated by VAS was significantly stronger (5 points) than in nonoperative leg (1 point). Postoperatively, patients reported significant decrease in knee pain. Three months after TKA, the knee pain was assessed by subjects on 3 points, 6 months after TKA on 1.6 points. KOOS indicated that three patient-relevant dimensions such as Pain, ADL Function, and knee-related Quality of Life were improved significantly 3 and 6 months after TKA (Fig. 2). Sport and Recreation Function scores were also higher than prior TKA, but the changes were not significant. Only other Disease-Specific Symptom scores were lower than before TKA, showing a tendency for improvement 6 months postoperatively.

Isometric MVC force of the operated leg was significantly lower before, 3 and 6 months after TKA when compared with the nonoperated leg (Fig. 3a). Three months after TKA, MVC force decreased significantly in the operated leg. Six months after TKA, there was a

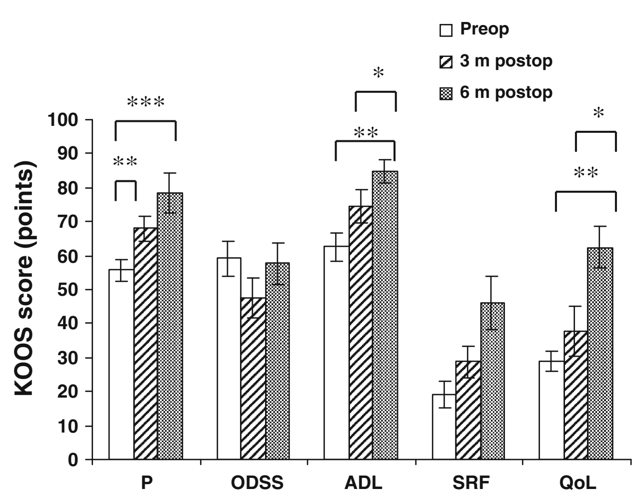

Fig. 2 KOOS in women with knee osteoarthritis ($n = 12$) before, 3 and 6 months after unilateral total knee arthroplasty. Values are mean ±SE. P- pain; *ODSS* other disease-specific symptoms, *ADL* activity of daily life, *SRF* sport and recreation function, *QoL* knee-related quality of life. $^*P < 0.05$; $^{**}P < 0.01$; $^{***}P < 0.001$

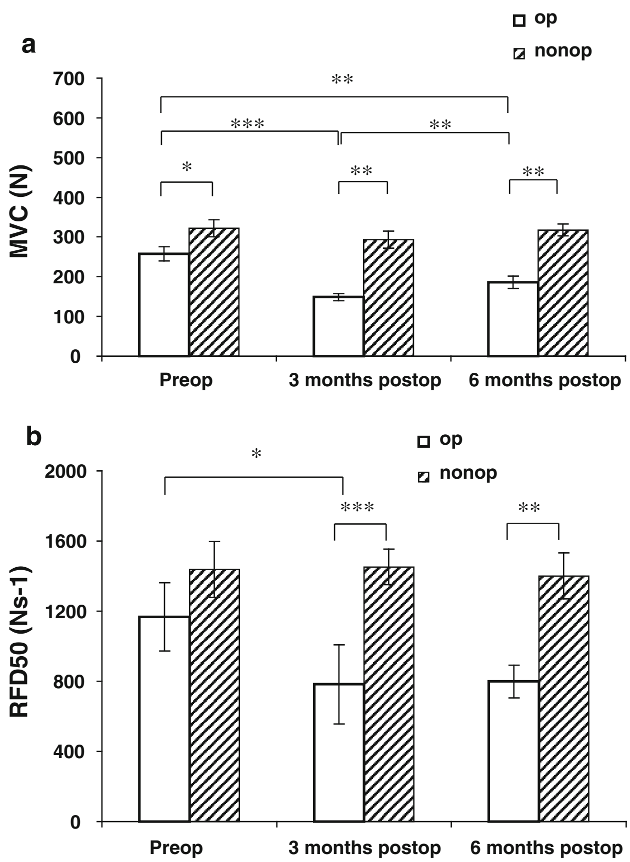

Fig. 3 Isometric maximal voluntary contraction (MVC) force (**a**) and rate of isometric force development at the level of 50% of MVC (RFD_{50}) (**b**) of the quadriceps femoris muscle in women with knee osteoarthritis ($n = 12$) before, 3 and 6 months after unilateral total knee arthroplasty. Values are mean ±SE. *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$

significant improvement of MVC force when compared to the same parameters 3 months after TKA. However, compared to the preoperative level, half a year after TKA, the MVC force in the operated leg was significantly lower. MVC force in the nonoperated leg was equal in strength before, 3 and 6 months after TKA.

RFD_{50} of the QF muscle in the operated leg was significantly lower 3 months after TKA, the significant difference persisted between the operated and nonoperated leg 3 and 6 months after TKA (Fig. 3b).

VA of the QF muscle did not differ significantly in the operated and nonoperated leg either before or 3 and 6 months after TKA (Fig. 4a). LATc of the QF muscle did not differ significantly between the operated and nonoperated leg before, 3 and 6 months after TKA (Fig. 4b). A significant shortening in LATc was suggested in the nonoperated leg 3 months after TKA. No significant prolongation of HRT in the operated and nonoperated leg was established neither before nor 3 and 6 months after operation (Fig. 4c).

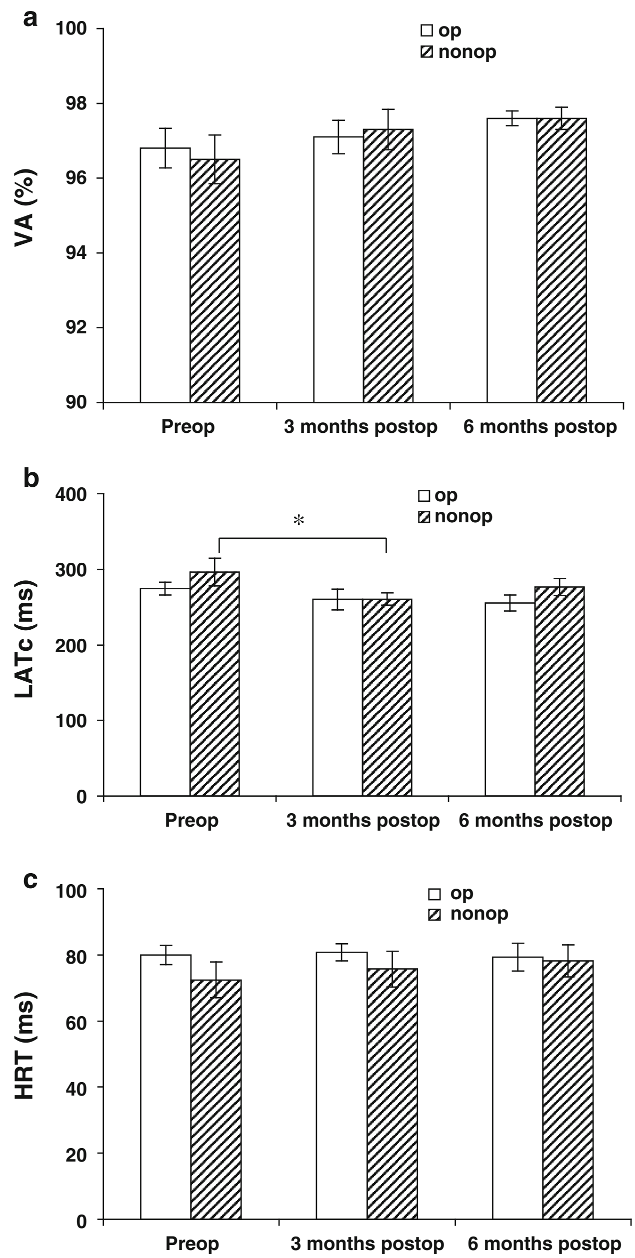

Fig. 4 Voluntary activation (VA) (**a**), latency of contraction (LATc) (**b**), and the half-relaxation time (HRT) (**c**) of the quadriceps femoris muscle in women with knee osteoarthritis ($n = 12$) before, 3 and 6 months after unilateral total knee arthroplasty. Values are mean ±SE. *$P < 0.05$

Discussion

The most important finding of the present study was that patients with knee OA have reduced maximal and explosive strength of the quadriceps femoris muscle with no changes in voluntary activation and capacity for rapid contraction and relaxation both before and after TKA.

Pain is common in the patients suffering from knee OA both before and during the 1 week after TKA. It is well known that TKA reliably reduces knee pain and improves knee functions [24]. In pain management includes both pharmacological treatment and physical therapy [11, 22]. In the present study, the subjects demonstrated 3 and 6 months after TKA a significant decrease in knee pain on the operated leg and significant increase in KOOS in almost every patient-relevant dimension. It can be confirmed that TKA and postoperative rehabilitation were effective to reduce knee pain and increase the quality of life in subjects with knee prosthesis.

As expected, the participants of the present study showed remarkable weakness of the QF muscle in the operated leg before, 3 and 6 months after unilateral TKA. MVC of the QF muscle in the operated leg compared to nonoperated leg was 18% lower before TKA, and significantly lower 3 and 6 months after TKA (47 and 39%, respectively). Comparing the same characteristics with the previous study [9], there was isometric MVC force deficit in the operated leg before and 6 months after TKA being 31 and 32%, respectively, and compared to controls being 48 and 44%. Twenty-six days after TKA was established the decrease in quadriceps strength was even 60% [32]. There are several explanations about QF muscle weakness in OA patients. Quadriceps strength is strongly associated with knee pain and disability in the community [24]. One cause of QF muscle weakness is the impairment in central nervous system activation [31]. Increased severity of joint damage may cause an increase in alteration of afferent inputs and subsequently a decrease in QF strength and VA [25]. Muscular coordination disorders are present already before surgery and are also caused by the implantation of a total knee arthroplasty [8]. Based on the results of the current study, where knee pain was reduced to a minimum and central nervous system activation was not impaired, may presume that the weakness of the QF muscle in patients with knee OA may be caused by muscular coordination or muscle power transfer error through ligaments attached to the bone. Postoperatively the power transfer is disturbed even more because of the prosthesis, the affected ligaments (including patellar ligament), and scar tissue does not allow a proper power transfer from muscle to ligament. It has been argued that coordination disorders can be improved by rehabilitation [8], but there is also evidence confirming that full recovery of the muscle strength and physical function to a normal level is rare [16, 37]. Because knee OA lasts for a long time and patients and rehabilitation specialists typically focus on muscle strength only after surgery, it is usual that patients achieve a strength level that is essential for everyday living and make no attempt to restore muscle strength to the opposite leg's level.

Explosive muscle strength characterized by rate of force development (RFD) is a term to describe the ability to rapidly develop muscular force during isometric conditions [1]. It has been found that voluntary RFD is dependent on MVC [1], and there exists an opinion that RDF shows larger side-to-side difference compared with MVC strength [16]. In the current study, isometric RFD_{50} of the QF muscle for involved leg was 17.5% lower as compared to uninvolved leg before TKA. This difference between the legs increased 3 and 6 months after TKA, being 48 and 42%, respectively. It is known that the rate of muscle force development is influenced by both central and peripheral components. The force generation results of the current study suggest that in patients with knee OA rapid neural activation of muscles, that is, recruitment of motor units does not differ during isometric MVC force or during rapid voluntary force production. For example, children with spastic diplegic cerebral palsy have relatively greater deficiency in the capacity of rapid voluntary force production (64% compared with controls) than in isometric MVC force of the QF muscle [34]. The patients with knee OA have a remarkable weakness of the QF muscle, so they are also unable to perform quicker moves in walking, ascending, or descending from a chair or stairs, etc. In the current study emerged a tendency for MVC and explosive force production improvement half a year after TKA. Postoperative QF muscle strength is a critical part of the success of TKA and is affected by the patient's preoperative comorbidities, surgical technique, and postoperative rehabilitation [10].

In the current study, the twitch interpolation technique was used to measure the level of VA or excitations of motoneurons of QF muscle. The method is called twitch interpolation because the stimulus consists of one single pulse [12]. To ensure that all motor units are activated during muscle contraction, several studies [4, 17, 31] have used double or multiple stimuli in an effort. However, there is a study [2] which confirms that single stimuli are equally effective in producing full activation as compared to stimuli applied as paired or in trains. During the last decade, several articles have been published, confirming that the failure of voluntary muscle activation, resulting from an inability to recruit all of the muscle's motor units, causes significant bilateral VA deficit in patients with knee osteoarthritis [3, 20, 21]. There are also studies [4, 9, 32] where VA of QF muscle did not differ between the involved and uninvolved leg. The current study demonstrated that patients with knee OA could nearly completely ($VA > 95\%$) activate the QF muscle during isometric MVC both before and after TKA. The same results with the same method were also yielded in TKA patients by Gapeyeva et al. [9]. When comparing young and elderly subjects, it was found in the study that despite reduced maximal force, there were no differences in the ability of young (mean age 26 years) and elderly (mean age 80 years) subjects to voluntarily activate their muscles [29]. It has also been found [14] that despite considerable less muscular strength in the older group, muscular activation was greater than 95% of maximum, being equal in both young and older individuals.

Due to contradictory results, arises the question about the sensitivity of the interpolated technique. Interpolated twitch technique is valid and reliable for analyzing high-intensity contractions [2]. It has been found [31] that there were no significant differences in the central activation ratio across train types during maximal efforts (75 and 100% of MVC; 100 Hz 120 ms train), but submaximal effort (25 and 50% of MVC; 100 Hz 250 ms; 50 Hz 500-ms) produced significantly lower central activation ratio. Therefore, it is important to determine the relationship between the central activation ratio and the level of muscle contraction.

Since the level of voluntary activation quantifies as an interpolated twitch ratio or central activation ratio [23], the results of the current study may suggest that despite reduced maximal force the patients with knee OA have good central activation for muscle contraction.

The reaction time to visual stimuli or latency of contraction (LATc) or rapid voluntary contraction assesses the preparation of isometric knee extension movement. Data of the current study indicated no significant differences in the LAT_C during unilateral MVC of the QF muscle in the operated leg either before or 3 and 6 months after TKA. Only the nonoperated leg contracted significantly more slowly during MVC 3 months after TKA as compared to the same characteristic before TKA. Despite the subjects having knee pain and QF muscle weakness, the rapid voluntary contraction was not prolonged and the movement preparation was not affected. There is contradictory information in literature about movement preparation of the QF muscle. Whereas one study confirms that the ability of the QF muscle to generate force rapidly and efficiently is diminished in persons with knee OA [18], the other declares that in patients with knee OA, compromised temporal parameters and magnitude of force generation during patellar tendon reflex reactions do not appear [6]. Understandably there were different methods used, allowing the authors to make appropriate conclusions, but the question remains—does there exist an impairment of neuromuscular function in patients with knee OA?

There is abundant information about MVC and VA of the QF muscle, but only one relevant article can be found about relaxation characteristics [9], the data of which coincide with the findings of this research. In the current study, no significant prolongation of HRT of the QF muscle was observed either between operated and nonoperated leg or before, 3 and 6 months after TKA.

Voluntary muscle relaxation occurs as a consequence of excitation of corticospinal projection neurons or intracortical inhibitory interneurons [36]. Both the presupplementary motor area and supplementary motor area proper play an important role in motor inhibition. On this basis, it can be considered that patients with knee OA have control over QF muscle contraction and relaxation. On the other hand, it is known that fatigue occurs as a result of repeated activation of skeletal muscle [36]. The subjects of the current study performed only nine individual efforts to measure QF muscle strength and its contractile properties. It is possible that such a short effort does not cause an excitation of corticospinal neurons, or individual muscle contraction did not cause the fatigue.

Individual physical therapy did not influence the results of VA, LATc, and HRT of the QF muscle; however, in patients, the knee pain was decreased, the quality of life significantly improved, and there was a tendency for MVC and explosive force production improvement half a year after TKA. All subjects of the current study received postoperative inpatient rehabilitation and exercise instructions for home. According to the training diaries, the average number of training days per week was four, with the duration of 25 min. The subjects performed during each workout 1–3 exercises from each group of exercises (strengthening, range of motion, balance and coordination, stretching). Three months after TKA, the loading of exercises was more specified. For example, 5 months after TKA, the knee extension with adjustable ankle weights (2 kg) was performed with 2 sets and 20 repetitions per set. General physical activity and operated leg's functionality were improved also by walking (9 patients), cycling (5 patients), swimming (4 patients), gardening (5 patients), and farm working (2 patients). Postoperative counseling and recommendations for performing exercises at home helped patients to participate in self-management of their condition and be responsible for their health.

Despite the fact that statistical power analysis demonstrated that twelve patients were sufficient to detect a significant difference, a small number of only female patients can be regarded as a limitation of the study. The present study demonstrated that in patients with knee OA, voluntary activation and capacity for rapid isometric contraction and relaxation of quadriceps femoris muscle are not disturbed, so future studies could focus on power transfer from muscle to ligament, possibly yielding better answers for the question, which structures disturb the full recovery of muscle after joint disease, trauma, or knee operation. The clinical importance of the study was the knowledge that patients with knee OA can rapidly contract and relax their QF muscles and consequently that muscle strength exercises could be performed more aggressively.

Conclusions

The present study demonstrated that maximal and explosive muscle strength of the quadriceps femoris muscle is remarkably reduced before and after TKA. However, voluntary activation and capacity for rapid isometric contraction and relaxation of the quadriceps femoris muscle are not disturbed in patients with knee OA either before or after TKA.

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