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Knee Muscles Power Evolution in Patients with Total Knee Arthroplasty

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Abstract
Purpose: To measure changes in muscle power from before to 6 months after total knee arthroplasty and to compare outcomes with those from a control group of healthy adults. *Material and Methods*: 26 patients who underwent a total knee replacement were compared with 12 healthy age-matched adults in a prospective cohort study. Patients' assessment was performed preoperatively, as well as at 1, 2 and 6 months postoperatively, by the isokinetic method. Healthy adults were assessed once by the same method. Isokinetic evaluation of knee extensor and flexor muscles was performed using a Gimnex Iso 2 dynamometer. After a warm-up protocol, measurements were done at angular velocities of 90 and 180°/sec. *Results*: Compared to healthy adults, patients performed significantly worse at all evaluation times, for both extensors and flexors of the knee, except for the 6-month evaluation at 180°/sec. One month postoperatively losses from preoperative levels were registered in patients, but without statistically significance, except for extension at 180°/sec. At 6 months postoperatively patients surpassed the preoperative levels, with statistical significance at 180°/sec. *Conclusions*: Power is an important parameter to follow after TKA, in parallel with peak torque. Increasing muscle power should be one of the central issues to address during postoperative rehabilitation.

Keywords: Arthroplasty; Muscle strength; Power; Isokinetic; Rehabilitation

Introduction

Osteoarthritis is the most prevalent joint disease and the major cause of pain and disability in the elderly [1]. Knee is one of its most frequent localization, due to the implication in gait, body weight bearing, stairs ascending and domestic activities. Pain, hypotrophy and failure in voluntary quadriceps muscle activation have been suggested as causes of strength reduction in knee osteoarthritis people, with a great functional impact [2].

Total knee arthroplasty is the final solution for individuals in advanced stages of osteoarthritis, able to eliminate pain and to improve function and quality of life. Most patients have excellent clinical results after surgery, but some functional problems, not always clinically and radiographically sustained, might persist [3]. Quadriceps muscle weakness has been systematically reported after TKA (total knee arthroplasty) [4]. Even when quadriceps strength improved as compared to preoperative level, it never reached values of healthy individuals of the same age [5].

Inflammatory reactions, deficit in volitional muscle activation and hypotrophy lead to reduction of muscle total work and consequently of torque, muscle power and resistance in patients with knee osteoarthritis and in those with TKA, usually interfering with individual's autonomy and quality of life [6].

In isokinetic tests, measures of peak torque, expressed in Newton*meter (Nm), although useful, represent performance at a certain point in the range of motion. Muscle total work, expressed in Joule (J), is the action of strength over a specific distance or, precisely, the action of torque during the range of motion. A low value indicates that the energy expenditure during the range of motion is not adequate. Muscle power, expressed in Watts (W), represents total work divided by contraction time or, precisely, energy expenditure during a contraction over a certain time [7]. So, a higher peak torque in one patient is no guarantee of greater total work output or of greater power generation than in another.

Because peak torque represents performance at a single point of the range of motion, it might not be a good indicator of total functional capacity. Muscle strength over the entire range of motion (work) and strength per unit of time (power) would be more clinically relevant [8].

Unfortunately, despite the impact of all these parameters on functional results, studies conducted on TKA patients tended to concentrate on peak torque effects rather than power or total work. On the other hand, the main part of the few studies assessing also power and total work in TKA patients are cross-sectional and have no control group, comparison being made with contralateral limb. Or, it has already been shown that approximately 40% of patients with unilateral TKA progressed to a TKA in their nonoperative lower extremity by 10 years [9]. Therefore, the uninvolved knee should probably not be considered a typically healthy or unimpaired joint.

The present study aimed to measure changes in muscle power from before to 6 months after total knee arthroplasty and to compare outcomes with those from a control group of healthy adults.

Material and Method

Selection and Description of Participants

In the present study there have been included 26 patients (19 females, 7 males) with advanced knee osteoarthritis and indication of total knee replacement, as well as 12 healthy adults (8 females, 4 males).

Patients proposed for TKA were consecutively recruited from 3 orthopaedic departments (Clinical Rehabilitation Hospital, Clinical Emergency Hospital and Military Hospital) from Cluj-Napoca, between June 2011 and February 2012. Inclusion criteria were knee osteoarthritis (according to American College of Rheumatology criteria) in end-stage, with TKA indication and age between 50 and 85 years. Exclusion criteria were: uncontrolled hypertension or diabetes, BMI (body mass index) greater than 35kg/m^2, significant neurologic impairments, significant contralateral knee osteoarthritis (stage 3 or 4 Kellgren-Lawrence) or other unstable lower extremity orthopaedic conditions. Following surgery, all patients participated in a standardized 4-week rehabilitation program at the Clinical Rehabilitation Hospital Cluj-Napoca (2 weeks in the orthopaedic and 2 weeks in the rehabilitation departments). The objectives of rehabilitation program were pain control, increasing knee range of motion, strengthening of quadriceps, hamstrings, hip abductors, hip extensors and ankle plantar flexors, gait correction.

Healthy adults (HA) were consecutively recruited from the community between January and April 2012. Healthy adults were included if their age was between 50 and 85 years and were excluded if they had knee osteoarthritis (according to American College of Rheumatology criteria) or any of the exclusion criteria listed above for the patients undergoing TKA.

An informed consent was obtained from all patients prior to the study. The study protocol was accepted by the Ethics Committee of the University, with the number 622/2012.

Methods: Technical Information

There have been 4 evaluation times for patients: preoperatively, 1, 2 and 6 months postoperatively. Healthy adults have been evaluated once. Performance of knee extensor and flexor muscles have been evaluated by the isokinetic method, using a Gimnex Iso 2 dynamomater. Evaluation began with a session of warm-up and familiarization, consisting of one set of 10 submaximal repetitions of knee flexion and extension at the velocity of 240°/sec. After a two-minute rest period, muscular performance was assessed by a set of 10 repetitions at the velocity of 180°/sec, followed by 5 repetitions at 90°/sec. Between sets, a two-minute rest interval reduced the effects of fatigue. The following parameters were automatically registered for both extensor and flexor muscles: peak torque, angle at peak torque, maximal power, total work, flexor/extensor ratio (for peak torque).

Isokinetic assessment is an objective method for muscle strength evaluation, with a high accuracy and reproducibility, much more precise than manual muscle testing. Its limitation derives from the need of a good patient collaboration, in order to develop maximal contractions.

Statistics

Quantitative variables were expressed as mean ± standard deviation (SD). Once the normal distribution of data had been confirmed by Kolmogorov-Smirnov test, statistical analysis of differences between the two groups was carried out using Student t test for independent samples (previously variance was tested). Sex and side distribution between groups was tested using a Pearson chi-squared statistic. Statistical analysis of values registered in the TKA group at the four different time points was carried out using repeated measures ANOVA test with post hoc Bonferroni correction. The percent variations in the TKA group were expressed as mean and 95% confidence interval, as provided by repeated measures ANOVA test. The statistical significance threshold was at $p \leq 0.05$. The software used was Microsoft Excel 8.0 for Windows and MedCalc 12 (trial version).

Results

There were no differences between healthy adults and patients undergoing TKA for age, sex or BMI (Table 1). Distribution of arthroplasty between the two sides was equilibrated in the patient group.

Table 1. Subjects demographic characteristics

Variable	TKA Group (mean±SD)	Healthy Adults Group (mean±SD)	Statistical significance (p)
Age (years)	66.83±6.83	67.25±7.18	>0.05
BMI (kg/m²)	30.64±5.24	33.27±3.51	>0.05
Sex (male/female)	7/19	4/8	>0.05
Side (left/right)	12/14	-	-

SD=standard deviation; TKA=total knee arthroplasty; BMI=body mass index.

The values registered at the isokinetic evaluation of muscular power are presented in Figures 1-4.

Maximal power in extensors at the velocity of 180°/sec was lower in patients than in control subjects at all evaluation times. One month after the knee arthroplasty an important loss of power from the preoperative level was registered, followed by a progressive recovery, so that at 6 months postoperatively maximal power was higher than before the surgical intervention.

The same pattern of variation for extensors power was registered also at the velocity of 90°/sec, as well as for the flexor muscles at both angular velocities.

The values of maximal power registered at 90°/sec were lower than those registered at 180°/sec, in both extensor and flexor muscles.

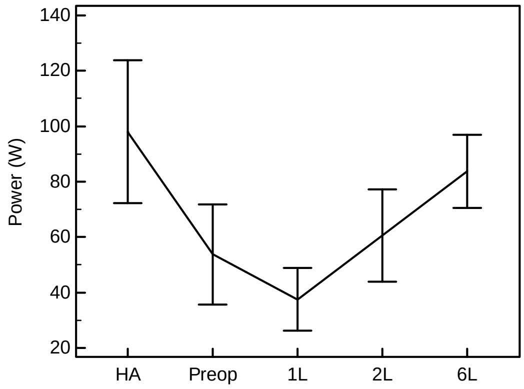

Figure 1. Evolution of maximal power in extensors at the velocity of 180°/sec

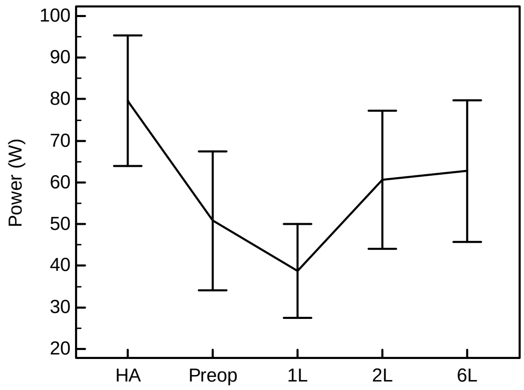

Figure 2. Evolution of maximal power in extensors at the velocity of 90°/sec

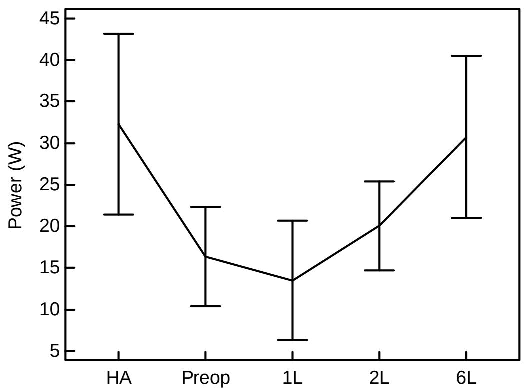

Figure 3. Evolution of maximal power in flexors at the velocity of 180°/sec

The values for the extensor muscle power were always higher than those obtained for the flexors, for a specified velocity.

Statistical significance of all these observations, as resulted from the Student t test application, is presented in Tables 2 and 3, as well as the evolution of the proportional power deficits in TKA patients.

Compared to healthy adults, patients awaiting TKA had 36.3% and 45.1% less quadriceps power (at the angular velocities of 90 and 180°/sec). The deficit aggravated at 51.4% and 61.7%, respectively, at one month postoperatively. The extensor power recovered until a deficit of 24% and 20.3%, respectively, at two months, for being of only 18.2% and 14.6%, respectively, at six months. Flexors power deficit, compared to healthy adults, varied from 35.4% and 49.5% preoperatively to 12.3% and 4.9% postoperatively. At all evaluation points, patients muscular power deficit was statistically significant (p<0.05), except for the evaluation at 6 months, when extensors and flexors power was not significantly different from that of healthy adults at 180°/sec velocity.

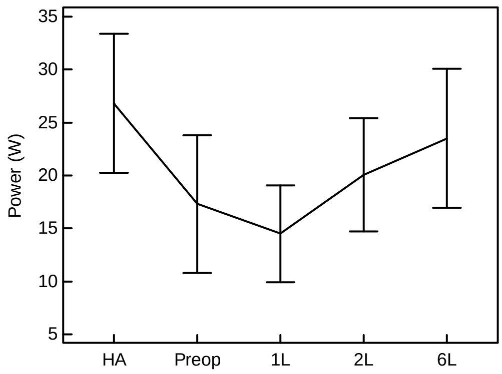

Figure 4. Evolution of maximal power in flexors at the velocity of 90°/sec

Table 2. Comparison of maximal power between TKA patients and healthy adults

Parameter	Difference HA-TKA Preop.		Difference HA-TKA 1M		Difference HA-TKA 2M		Difference HA-TKA 6M	
	p^a	% (95%CI)	p^a	% (95%CI)	p^a	% (95%CI)	p^a	% (95%CI)
P E 180°/s‡ (W)	0.04*	45.1 (21.9;68.3)	0.01*	61.7 (25.9;97.5)	0.04*	20.3 (5.2;35.4)	0.09	14.6 (-6.1;35.3)
P E 90°/s‡ (W)	0.02*	36.3 (17.7;54.9)	0.02*	51.4 (23.7;79.1)	0.02*	24.0 (12.3;35.7)	0.03*	18.2 (9.1;29.3)
P F 180°/s‡ (W)	0.01*	49.5 (26.7;72.3)	0.01*	58.2 (26.8;89.6)	0.03*	25.4 (10.5;40.3)	0.2	4.9 (-7.4;17.2)
P F 90°/s‡ (W)	0.04*	35.4 (6.3;64.5)	0.04*	45.9 (23.8;68.0)	0.02*	25.0 (7.4;42.6)	0.04*	12.3 (5.8;18.8)

P E =power of extensors; P F=power of flexors; ‡=p ANOVA<0.05; p^a=p Bonferroni corrected; * - p<0.05; %Difference HA-TKA_x=(HA-TKAx)*100/HA, where HA=mean of maximal power in HA group, TKAx= mean of maximal power in patient group at the x time of evaluation; preop=preoperatively, 1M=1 month postoperatively, 2M=2 months postoperatively, 6M=6 months postoperatively; HA=healthy adults group; TKA=total knee arthroplasty group; CI=confidence interval.

Table 3. Comparison between preoperative and postoperative values of maximal power in TKA patients

Parameter	Difference Preop-1M		Difference Preop-2M		Difference Preop-6M	
	p^a	% (95%CI)	p^a	% (95%CI)	p^a	% (95%CI)
P E 180°/s‡ (W)	0.01*	30.3 (16.1;44.5)	0.12	-45.2 (-95.3;4.9)	0.03*	-55.6 (-92.9;-18.3)
P E 90°/s (W)	0.42	23.8 (-8.7;56.3)	0.35	-19.3 (-42.8;4.2)	0.56	-28.3 (-65.5;8.9)
P F 180°/s‡ (W)	0.27	17.2 (-3.5;37.9)	0.27	-47.8 (-98.1;2.5)	0.04*	-88.3 (-115.4;-61.2)
P F 90°/s (W)	0.63	16.2 (-1.2;33.6)	0.72	-16.2 (-42.0;9.6)	0.48	-35.8 (-83.3;11.7)

P E =power of extensors; P F=power of flexors; ‡=p ANOVA<0.05; p^a=p Bonferroni corrected; * - p<0.05; %Difference Preop-xM=(Preop-TKAx)*100/Preop, where Preop=mean of maximal power preoperatively in TKA group, xM= mean of maximal power at x months in TKA group; TKA=total knee arthroplasty; CI=confidence interval.

One month after surgery, compared to preoperative levels, patients experienced a decrease in quadriceps power by 23.8% and 30.3% (at the angular velocities of 90 and 180°/sec), but with statistical significance ($p<0.05$) only at 180°/sec. At two months they already surpassed the preoperative levels, but without statistical significance ($p>0.05$). At six months quadriceps power increased by 28.3% and 55.6%, respectively, compared to preoperative levels, with statistical significance ($p<0.05$) for the velocity of 180°/sec. Flexors power evolution respected the same pattern, without statistical significance, except for the 6 months evaluation, when flexors power was significantly higher than preoperatively ($p<0.05$) at 180°/sec velocity.

Discussion

In the present study muscular power was isokinetically assessed before and 1, 2 and 6 months after total knee replacement in osteoarthritis patients, comparatively with healthy age-matched adults. It was observed that, preoperatively, patients generated less power than their healthy mates on both knee extensors and flexors. The deficit aggravated one month after the surgery and progressively recovered afterwards until 6 months. This evolution generally followed that reported by the authors for isokinetic peak torque of knee muscles after TKA [10]. In the studies where muscle strength was assessed by other methods (mainly isometrically) the same evolution was found [4,5,11].

What we found different in this study was that power deficit was less important than that of muscular torque and recovered quicker to the preoperative level. Even more, in some cases it came close to healthy adults values. Thus, even if a power loss was noticed at one month after TKA, statistically significance was met only for extension and only at the angular velocity of 180°/sec. Concerning this difference between extensors and flexors evolution, Rossi also found, but for peak torque, that there was asymmetry between limbs before and one year after TKA, although extensors dysfunction was more pronounced than flexors dysfunction [12]. At two months, we found that power had already recovered to preoperative levels and even surpassed them, but without statistically significance. At 6 months, power values were significantly greater than preoperatively for the angular velocity of 180°/sec, for both extensor and flexor muscles. At the same time, at 180°/sec the 6-month power values were no longer significantly different from those of healthy adults.

Concerning the influence of the angular velocity, it was already shown that power outputs increase with increased speed of motion, even if torque and work outputs decreased [13].

Overall, the deficit in knee extension torque after TKA was found as considerable and prolonged in previous studies: between 15 and 29%, comparatively to the nonoperated limb, lasting up to 13 years in some cases [14-16]. The flexor torque deficit was between 16 and 23% comparatively to the nonoperated limb at 6 to 12 months after surgery [10,14].

In a cross-sectional study, Valtonen et al. found also that deficits in muscle torque and power for both extensors and flexors were present 10 months after knee replacement, when compared with contralateral side, potentially causing mobility limitations [17]. Thus, a larger knee extension power deficit predicted slower stair-ascending and stair-descending times. Lamb found also a deficit of 18% in leg extension power at 6 months after knee replacement [18]. Bastiani et al compared TKA patients at more than one year from the surgery to nonoperated knee osteoarthritis patients and found no differences between groups concerning work and power at the angular velocity of 60 and 240°/sec [8].

Power deficits have also been reported in other knee musculoskeletal disorders. Thus, in rheumatoid arthritis peak torque, total work and power were lower than in healthy adults [19]. After patellectomy, quadriceps power was 60% of that of the contralateral healthy knee [20]. Neeter et all. observed a power deficit in 90% of the patients with anterior cross ligament injury and in 69% of those whose ligament had been reconstructed [21].

The authors reporting a deficit in functional capacity after TKA agreed that the persistent weakness of the quadriceps might be due to a failure in current rehabilitation programs or to their complete absence [8]. In our study patients were included in a standard rehabilitation program immediately after surgery, continued for two weeks in the orthopedic department, followed by another two weeks in the rehabilitation department. Some authors emphasized the importance of identifying functional problems after TKA, so that treatment can be specifically focused on the impairment, leading to clinical improvement [3]. The use of more appropriate rehabilitation programs, with exercises that emphasize strong muscle contractions might be necessary to restore strength in patients with TKA, although the effects of such therapies have not yet been clarified [6,8]. Power deficit should also be taken into account in rehabilitation programs, because in daily activities it is important to have the muscle power needed to produce effective force quickly to generate desirable or prevent undesirable movements [17]. These programs could be very helpful in the years immediately after surgery and, especially, allow patients to preserve their functional capacity and maintain their independence for a long period of time [22].

The original contribution of this study consists in the dynamic follow up of the muscle power in TKA patients for the first 6 months after the surgery, comparatively to healthy adults. At the same time, it has been shown that, after knee replacement, power values could surpass the preoperative values and even attain those of healthy subjects. But literature is still inconsistent regarding muscle power in patients with TKA and the results of the present study need to be confirmed in further, larger studies on this population.

Conclusions

Power is an important parameter to follow after TKA, in parallel with peak torque. With appropriate rehabilitation, at 6 months postoperatively extensors and flexors power surpassed preoperative values and even came close to those of healthy adults. Therefore, increasing muscle power should be one of the central issues to address during the postoperative rehabilitation.

List of abbreviations

BMI – body mass index
HA – healthy adults
M – months
Preop - preoperatively
TKA – total knee arthroplasty

Conflict of Interest

The authors declare that they have no conflict of interest.

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