

Work and power of the knee flexor and extensor muscles in patients with osteoarthritis and after total knee arthroplasty

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ABSTRACT

Introduction: The inflammatory manifestations of knee osteoarthritis (OA) lead to muscle inhibition and hypotrophy, resulting in a reduction in total muscle work and muscle power. Total knee arthroplasty (TKA) is the most adequate surgery for the treatment of advanced OA. However, its effects on muscle functional behavior have not been well understood. **Objective:** To compare the total work and power of the knee flexor and extensor muscles in patients with OA (20) and in patients post-TKA (12) at two angular velocities (60°/sec and 240°/sec). **Methods:** An isokinetic Biodex dynamometer was used to assess muscle power and total work during isokinetic contractions. Two-way ANOVA for repeated measures was used to compare total muscle work and muscle power between the groups (SPSS software, version 13.0; significance level, $P < 0.05$). **Results:** There was no difference between the OA and TKA groups for the total work of both knee extensors and flexors at the two angular velocities ($P \geq 0.05$). In addition, no difference was observed in the muscle power of the knee extensors and flexors ($P \geq 0.05$). **Conclusion:** Total work and power were similar in the OA and TKA groups, suggesting that TKA did not improve functional capacity, which was similar in both groups.

Keywords: knee osteoarthritis, total knee arthroplasty, dynamometer.

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INTRODUCTION

Population ageing is a reality in Brazil, as is worldwide. Consequently, an increase in diseases associated with advanced age, especially the chronic degenerative ones, has been observed.¹ As age advances, there is a reduction in skeletal muscle mass (sarcopenia), and, thus, muscle weakness and increased joint overload occur.^{2,3}

Due to changes in muscle mechanics and joint overload, adaptations occur, leading to joint instability, strength change, and muscle inhibition, and, consequently, to increased vulnerability to muscle lesions and fatigue.^{3,4} This can result in overload change and joint degeneration due to the reduced ability of the muscle system to absorb repeated impacts, which has

been suggested to be a risk factor for the development and/or worsening of osteoarthritis (OA).⁴⁻⁶

OA is the most prevalent joint disease and also the major cause of pain and physical disability in the elderly population.⁵⁻⁷ It is a degenerative disease that leads to joint cartilage loss, marginal osteophyte formation, and changes in the ligaments, synovial membranes, meniscus, and subchondral bone.⁸ Although the causes of OA are not yet well understood, items such as biomechanical stresses, biochemical changes in cartilage and synovial membrane, and genetic factors are important in its pathogenesis.^{9,10}

In the lower limbs, OA has a great impact on the knees and hips, because such joints bear all body weight, being fundamental to the gait, overcoming obstacles, such as stairs, and

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domestic activities.¹¹ In OA of the knee, edema and synovial thickening lead to a reflex inhibition of the quadriceps muscle, causing subsequent muscle hypotrophy. Pain, hypotrophy, and failure in voluntary quadriceps muscle activation have been suggested as causes of strength reduction in both individuals with knee OA and the elderly, generating important functional impact.^{4,9,12-14}

Surgery is indicated for the more advanced stages of disease, in which greater cartilage and bone degenerations are evident, and where there is already impairment of the three knee joint surfaces, joint function alterations and pain.¹⁵ Patients with grade II and III OA and progressive impairment of autonomy in daily life activities, in addition to failure in conservative treatment, should be referred to the orthopedist, who will indicate surgical treatment.¹⁶ The most used procedure in such cases is total knee arthroplasty (TKA),¹⁷ in which the joint is totally replaced by a total prosthesis. It is mainly aimed at pain reduction, functional rehabilitation, and quality of life improvement.¹⁸⁻²² Most patients undergoing TKA have excellent clinical results; however, some dysfunctions related to functional problems, not always clinically or radiographically evident, might persist.^{17,18,22,23}

Quadriceps muscle weakness after TKA has been reported by several authors as normal.^{19,23,24} Many studies have reported a reduction in the quadriceps muscle strength, in the voluntary muscle activation, and in the cross-sectional area (CSA) after TKA as compared with pre-operative values.^{22,23,25} Even authors who have reported an improvement in quadriceps muscle strength in individuals after TKA have not observed total recovery as compared with healthy individuals in the same age group.^{18,26,27}

The inflammatory manifestations, deficit in voluntary muscle activation, and hypotrophy of patients with knee OA and those undergoing TKA are believed to lower total muscle work,^{28,29} leading to a reduction in torque, muscle power³⁰ and resistance. This generates important functional capacity loss, predisposing such individuals to fatigue.¹²

The reduction in total muscle work and the consequent muscle power loss due to osteoarticular diseases usually interferes with the individual's autonomy and quality of life.^{2,29-31} Despite the impact on functional results, quadriceps muscle work and power have not been typically assessed in post-operative studies of TKA. Thus, those functional variables should be investigated in studies of populations with knee OA and TKA. In addition, the adaptive processes of musculoskeletal tissues to joint degeneration and replacement of the damaged joint by a prosthesis need to be better established. Any effort to clarify the mechanisms related to that disease aimed at reducing

or delaying its effects is highly important. Thus, the present study aimed at comparing muscle performance regarding total work and power of the knee flexor and extensor muscles in individuals with knee OA and after TKA.

MATERIAL AND METHODS

Sample

This study sample comprised 32 individuals of both genders, over the age of 50 years, divided into the following two groups: the OA group, comprised by 20 individuals with grade II, III, and IV OA of the knee (Dejour classification, 1991);¹⁵ and the TKA group, comprised by 12 individuals in the post-operative period of TKA (range of one to three years).

The individuals were selected intentionally based on the clinical assessment by a physician specialized in Orthopedics and Traumatology (Service of Orthopedics and Traumatology of the Hospital São Lucas, PUC-RS). For the individuals with OA, X-rays (in the anteroposterior and lateral views, monopodal stance) were requested to confirm the OA diagnosis and grading. The TKA group comprised only individuals who had undergone surgery one to three years before, based on a previous history of primary knee OA. In addition, they should all have undergone the same surgical technique, received the same prosthesis model (MB-VI, Metabio), and had the same post-operative period.

The exclusion criteria were as follows: previous history of hip joint surgery and/or revision knee surgery; severe pain assessed by use of the visual analogue scale of pain (VASP); limitation of range of motion of the knee; and cardiac, neurological, musculoskeletal, and metabolic changes that hindered the execution of maximal voluntary contraction tests.³² The Humac[®] recommendations were also respected.³³

Participants were assessed regarding their functionality degree (Western Ontario and McMaster Universities Osteoarthritis Index - WOMAC Index)^{34,35} and pain intensity (VASP).³⁶

This study was approved by the Ethics Committee in Research of the Universidade Federal do Rio Grande do Sul (protocol #2007740). After being instructed about the procedures that would be performed, the participants provided written informed consent, assuring their rights according to resolution #196/96 of the Brazilian Health Board.

Instrumentation

To assess total work and muscle power, the isokinetic dynamometer Biodex System 3 Pro (Biodex Medical Systems, Shirley, New York, USA) was used.³³

Procedures

The individuals were positioned in the dynamometer according to the manufacturer's instructions. Then, they underwent a session of warm-up and familiarization, with one set of ten submaximal repetitions of knee flexion and extension at the velocity of 120°/sec. After a two-minute rest, total muscle work and muscle power were assessed with a set of five repetitions at the velocity of 60°/sec, and a set of 20 repetitions at the velocity of 240°/sec.^{37,38} Between the sets, a two-minute interval was observed to minimize the effects of fatigue. During the isokinetic tests, the same verbal stimulus for maximal effort was provided to all participants.³⁹

At the end of the assessment protocol, stretching was performed and ice was applied to the knee joint for 20 minutes, aiming at preventing possible muscle discomfort due to the unusual maximal effort. All individuals received a program of home exercises for muscle reinforcement and stretching to aid with their functional recovery.

Statistical analysis

Quantitative variables were described as mean, standard deviation, median, skewness, and kurtosis. To assess data normality and homogeneity, the Shapiro Wilk and Levene tests were performed, respectively. Based on this analysis, the data were considered normal, and parametric statistical analysis was adopted.

Two-way analysis of variance (two-way ANOVA) for repeated measures was used for comparing the differences between the groups regarding the variables total muscle work and muscle power. The *post-hoc* Bonferroni test was used to identify the differences between the groups. One-way ANOVA with *post-hoc* Bonferroni test were used to compare the sample characterization variables between the groups.

The SPSS (Statistical Package for the Social Sciences) software, version 13.0, was used for statistical analysis, and the significance level adopted for all analyses was $P < 0.05$.

RESULTS

The sample comprised 32 individuals divided into two groups. The OA group consisted of 20 individuals (14 women and six men) with ages ranging from 52 to 76 years (63.0 ± 7.24). The TKA group consisted of 12 individuals (six women and six men) with ages ranging from 56 to 81 years (69.9 ± 7.83). Table 1 shows the characteristics of the sample concerning age and body mass index (BMI). The groups differed regarding

age ($P = 0.028$), which was higher in the TKA group. No difference in BMI was observed between the groups ($P = 0.493$).

Figures 1 and 2 show the results of total work of the knee extensor and flexor muscles obtained for the two groups at the two angular velocities assessed. Comparing the groups, differences were observed between the total work performed by neither the extensor muscles at the velocities of 60°/sec ($P = 0.198$) and 240°/sec ($P = 0.125$), nor the flexor muscles at the velocities of 60°/sec ($P = 0.180$) and 240°/sec ($P = 0.081$). Both groups had similar behaviors regarding the total work performed by the knee muscles at the angular velocities of 60°/sec and 240°/sec.

Similarly to total muscle work, OA and TKA groups also showed similar behaviors regarding muscle power at both angular velocities, and differences were observed for neither the knee extensor muscles at the velocities of 60°/sec ($P = 0.297$) and 240°/sec ($P = 0.163$), nor the knee flexor muscles at the velocities of 60°/sec ($P = 0.300$) and 240°/sec ($P = 0.121$), as shown in Figures 3 and 4.

Table 1

Characterization of the sample regarding age and body mass index (mean \pm SD)

Group	n	Men	Women	Age (years)	BMI
OA	20	6	14	63.0 ± 7.24	30.45 ± 3.77
TKA	12	6	6	$69.9 \pm 7.83^*$	31.65 ± 7.17

* $P = 0.028$. BMI: body mass index.

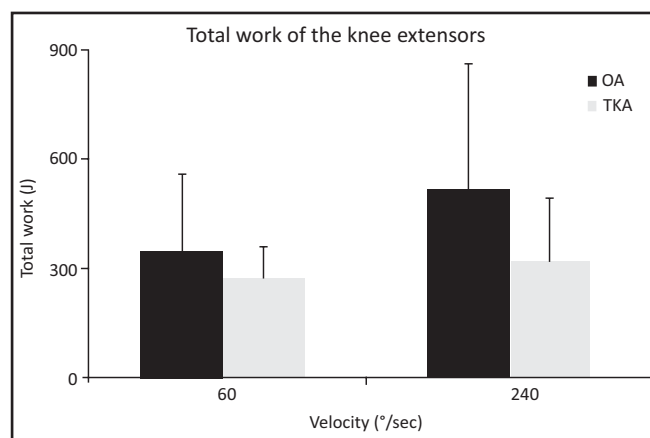


Figure 1

Total work of the knee extensor muscles of the OA and TKA groups at the angular velocities of 60°/sec ($P = 0.198$) and 240°/sec ($P = 0.125$).

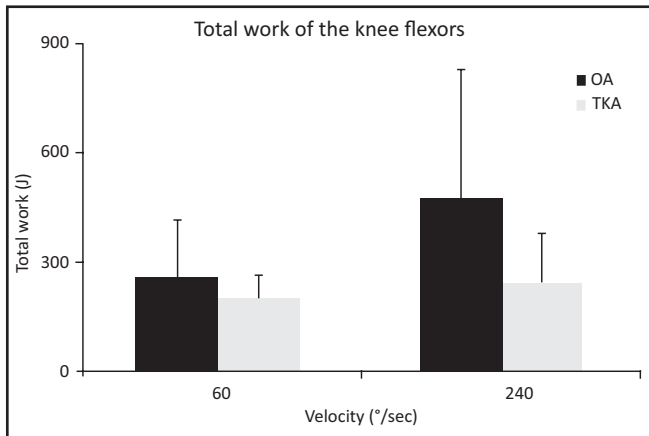


Figure 2
Total work of the knee flexor muscles of the OA and TKA groups at the angular velocities of 60°/sec (P = 0.180) and 240°/sec (P = 0.081).

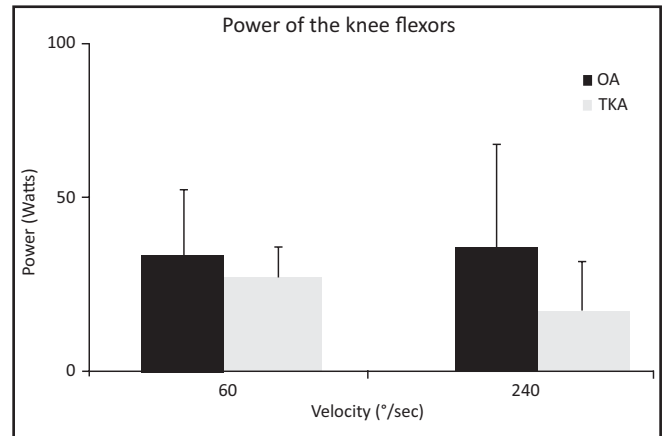


Figure 4
Power of the knee flexor muscles of the OA and TKA groups at the angular velocities of 60°/sec (P = 0.300) and 240°/s (P = 0.121).

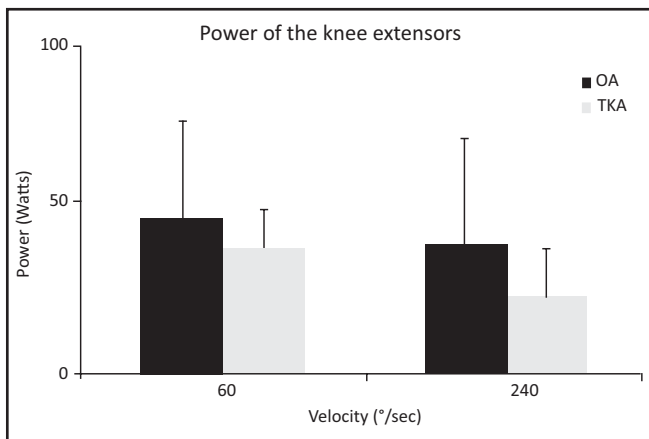


Figure 3
Power of the knee extensor muscles of the OA and TKA groups at the angular velocities of 60°/sec (P = 0.297) and 240°/sec (P = 0.163).

Significant difference (P = 0.022) was found in the total WOMAC index between the OA and TKA groups, with greater values for the OA group. In general, the pain values were close to zero, mainly at the end of the evaluations. When comparing pain between the groups, a significant difference in the mean pain value was observed, with lower values in the TKA group (P < 0.05), as shown in Table 2. However, difference regarding pain was observed neither between the pre-test and post-test period, nor between groups.

Table 2

Visual analogue scale of pain at three segments: pain, pre-assessment pain, and post-assessment pain (mean)

	OA group	TKA group	P
Pain	0.45	0.04	0.014*
Pre-assessment pain	0.37	0.03	0.207
Post-assessment pain	0.17	0.00	0.258
P = (pre- x post-)	0.352	0.337	-

* Significant difference.

DISCUSSION

Several researchers have investigated the alterations in the muscle strength of individuals with OA and TKA by assessing torque.^{3,13,15,18,26,27} 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. Thus, muscle strength over the entire range of motion (work) and strength per unit of time (power) would be more clinically relevant. However, such variables are not regularly assessed in studies of populations with knee OA and of post-operative results of TKA.³¹ Thus, the present study aimed at comparing muscle performance regarding total work and power of the knee extensor and flexor muscles between a group of individuals with knee OA and a group of individuals submitted to TKA.

Total muscle work is the action of strength over a specific distance, that is, the action of torque during the range of motion. That variable is calculated by use of the area under the curve for torque, which physically is the energy developed by the muscle. A low value can indicate that the muscle function is clinically altered and that the energy expenditure during a range of motion is not adequate or has muscle deficit.^{12,32} On the other hand, muscle power expressed in Watts (W) represents total work divided by contraction time, that is, energy expenditure during a contraction over a certain time. It clinically represents the amount of energy that the muscle can waste over a shorter time to generate torque, and can be altered due to some muscle functional deficit.^{12,32}

Because knee OA causes a reduction in muscle mass due to reflex muscle inhibition resulting from pain,^{10,14} and TKA is aimed at reverting the effects of pain by removing the tissues degenerated by OA,^{20,27} the TKA group was expected to show higher muscle work and power as compared with those of the OA group. However, the results showed no difference between the groups at the angular velocities assessed for both the knee extensor and flexor muscles.

Byrne et al.²² have investigated the functional alterations in the lower limb joints resulting from TKA, by comparing muscle work and power between healthy individuals and individuals after undergoing TKA. The work for the knee muscles was lower in the latter group than in the control group, and such deficit was compensated by the increase in the work performed by the hip extensor muscles.

A study by Walsh et al.²⁵ has assessed the walking velocity, ability to climb stairs, knee torque, and total work in 29 women one year after TKA and in 40 healthy women. The individuals undergoing TKA showed lower values for all those variables as compared with the control group. Those authors have reported that the strength deficit in the non-operated upon knee remains up to one year after surgery, which explains the decrease in the work of the extensor muscles. On the other hand, Aquino and Leme⁴⁰ have found no difference regarding the total work of the flexor and extensor muscles between patients undergoing TKA and healthy individuals.

Work and power of the knee muscles have also been assessed in studies on other knee musculoskeletal disorders. Meireles et al.¹² have assessed knee peak torque, total work, and power of 50 patients with rheumatoid arthritis (RA) and 50 healthy individuals, comparing them at angular velocities of 60°/sec, 80°/sec, and 300°/sec. All variables of patients with RA were lower than those of controls.

Lennox et al.⁴¹ have assessed 16 patients undergoing unilateral patellectomy, and their mean quadriceps muscle power was 60% of that of the contralateral healthy knee. The maximal

torque and mean work produced during eccentric and concentric contractions were one-third lower in the operated – side as compared with those of the contralateral muscle. Those authors have reported that muscle strength is not recovered immediately after patellectomy, but with a long-term rehabilitation program it can be restored.

Neeter et al.⁴² have assessed the muscle power of knee extensors and flexors in 23 patients with anterior cruciate ligament (ACL) injury and 44 patients after reconstruction of that same ligament, six months after injury and surgery, respectively. Those authors have compared the values obtained with those of the non-affected sides of those patients and with those of other 13 healthy individuals. In 90% of the patients with ACL injury and in 60% of those whose ACL had been reconstructed, a deficit in muscle power was observed.

Although the literature is not clear about whether that which is valid for peak torque is valid for work production and mean power,^{28–30} the data of studies assessing muscle strength only by use of torque should be analyzed along with the results of the present study.

Some authors, comparing voluntary muscle strength and activation in patients with primary knee OA before and after TKA, have reported a reduction in the quadriceps muscle strength and activation after surgery. They have reported that, despite the reduction in pain and improvement in the range of motion in the knee, quadriceps muscle weakness and reduction in functional capacity were typically present, even one year after surgery.^{13,21} A reduction in the quadriceps muscle strength is observed in long-term post-operative assessments, and correlates with functional limitations present prior to the surgical procedure of individuals with knee OA.³ The occurrence of a muscle strength deficit after TKA has been reported in some studies as normal.^{12,15} On the other hand, Berth et al.,¹⁸ in a study with patients assessed three years after TKA, have demonstrated that voluntary muscle activation improved over time, but did not reach the levels of healthy individuals. Anchuela et al.²⁶ and Lorentzen et al.²⁷ have also reported similar results, with greater capacity of strength production after surgery.

The authors reporting a deficit in functional capacity after TKA have agreed that the persistent weakness of the quadriceps muscle of those patients might be due to a failure in current rehabilitation programs in directing their action to the deficit in activation in the first week right after surgery. The results found in this study, demonstrating no difference in muscle performance regarding work and power between patients with OA and after TKA, might be, at least in part, due to the fact that individuals undergoing surgery have not received any physical therapeutic intervention other than hospital care, contributing

to the permanence of the functional deficit. Lennox *et al.*⁴¹ have suggested that if the patients assessed in their study underwent rehabilitation, the success rate of surgery might have been higher.

Total knee arthroplasty is the last resource for individuals with degenerative OA, to eliminate pain and improve function. There are several ways to assess the evolution of individuals undergoing TKA, in addition to assessing total muscle work and muscle power, the individual's functionality and quality of life can also be assessed by use of questionnaires, such as the WOMAC index.

The scores of the WOMAC index questionnaire differed between the OA and TKA groups. The TKA group scored lower than the OA group for the total WOMAC, pain, stiffness, and functionality. Although the groups assessed did not differ regarding muscle work and muscle power, they did differ in the WOMAC. Thus, placing a total knee prosthesis without subsequent physical therapy does not improve the mechanical properties assessed in this study, but improves the individual's quality of life and pain.

All individuals were asked about the pain in their injured knee, since the initial interview on the assessment day until the final assessment. A rule representing the VASP in a 0–10 scale was shown to the participants. In general, pain levels were close to zero, mainly by the end of the assessments. Comparing the pain levels between the groups, a significant difference was observed in mean pain, with lower levels for the TKA group.

Comparing the pre- and post-test pain levels, a difference was found neither between the groups nor between the assessment times. Several studies have shown a significant improvement in physical and psychological capacities in the post-operative period of TKA as compared with the pre-operative period. In studies showing that improvement, all participants received physical therapeutic care after surgery until total rehabilitation.^{43,44} Other authors, however, have found a correlation between the presence of pain, depression, OA, and alteration in functionality.⁴⁵

Several patients can have problems, such as muscle weakness and contracture, reduced range of motion, difficulty in walking, and limitation of daily life activities, despite replacing the injured joint with a prosthesis. Unfortunately, that reduction in functional capacity has been accepted by several authors as a normal functional deficit.^{25,45} Ulrich *et al.*²³ have emphasized the importance of using some techniques to identify functional problems after TKA, so that the treatment can be specifically focused on the impairment, leading to success of the clinical results for that population. The use of more appropriate rehabilitation programs, with exercises that emphasize strong muscle contractions, and clinical tools that facilitate muscle activation, such as biofeedback and neuromuscular electric stimulation, might be necessary to reverse the failure in muscle activation and weakness in patients with OA and after TKA, although the effects of such therapies have not yet been clarified.^{14,18,30} Such programs should benefit patients with orthopedic problems in the years immediately after surgery, and, even more important, should help them to preserve their functional capacity and maintain their independence for a long period of time.^{25,46}

The literature about the functional results of the TKA, especially regarding total muscle work and muscle power of the knee, is still inconsistent, indicating the need for further studies with that population. Studies about different types of rehabilitation are also relevant in the search for clarification on the OA-related mechanisms and the factors that can potentiate the benefits of TKA.

CONCLUSION

No difference between the OA and TKA groups was observed for total muscle work and muscle power at the angular velocities of 60°/sec and 240°/sec, both for knee extensors and flexors. The results of this study, for the patients assessed, suggest that TKA does not improve the functional capacity of the patients' musculoskeletal system as compared with that of patients with OA.

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