ARCHIVES OF HELLENIC MEDICINE: ISSN 11-05-3992

ORIGINAL PAPER
ΕΡΕΥΝΗΤΙΚΗ ΕΡΓΑΣΙΑ

ARCHIVES OF HELLENIC MEDICINE 2017, 34(3):363–372
ΑΡΧΕΙΑ ΕΛΛΗΝΙΚΗΣ ΙΑΤΡΙΚΗΣ 2017, 34(3):363–372

The relationship between isokinetic strength and functional performance 12 months after total knee arthroplasty

I. Poulis,[1]
K. Vassis,[1]
E. Kapreli,[1]
T. Chados,[2]
S. Chados,[3]
A. Kanellopoulos[1]

[1]*Department of Physical Therapy, Technological Educational Institute of Central Greece, Lamia*
[2]*Aristotle University of Thessaloniki, Thessaloniki*
[3]*General Hospital of Lamia, Lamia, Greece*

OBJECTIVE **To measure the correlation between isokinetic peak knee strength and functional performance 12 months after unilateral total knee arthroplasty (TKA).** METHOD **The study participants, 15 patients who had undergone primary unilateral TKA, were tested at least 12 months postoperatively. Isokinetic quadriceps and hamstrings torque were assessed in the operated and non-operated legs using an electromechanical dynamometer at the angular velocities of 60°/s and 180°/s. Functional performance was assessed using the stair-climbing test (SCT), the Timed "Up-and-Go" test (TUG), and the 6-minute walk test (6MWT).** RESULTS **Peak strength across two isokinetic velocities of the muscles of the knee was found to be correlated with the functional performance measurements. Functional performance on all three tests was significantly associated with the peak strength of the extensor muscles across both the isokinetic velocities. The 6MWT was significantly associated with peak torque of the flexor muscles across both isokinetic velocities. The only significant difference between the mean peak torque of the two knees was for the extensors at a velocity of 180°/sec. At this velocity, the mean peak torque of the extensor muscles of the operated leg was significantly weaker than that of the muscles in the non-operated leg. No difference was found between the flexor muscles of the operated and the non-operated leg at either 60°/sec and 180°/sec.** CONCLUSIONS **Measurement of knee extensor strength may be a useful tool for clinicians in assessing and setting milestones during rehabilitation after TKA.**

Σχέση μεταξύ μέσης μέγιστης ισοκινητικής ροπής και λειτουργικής απόδοσης, 12 μήνες μετά από ολική αρθροπλαστική γόνατος

Περίληψη στο τέλος του άρθρου

Key words

Functional performance
Knee replacement
Outcome assessment
Strength

Submitted 8.7.2016
Accepted 29.7.2016

The population in Greece is ageing, as it is worldwide, and arthritis related to ageing is the leading cause of disability. The joints most commonly affected are the knees and hips, and those in the hands and spine. Osteoarthritis (OA) of the knee is the most common disease of joints in older adults around the world.[1] Epidemiological data lead to the conclusion that OA of the knee is becoming a major health problem, affecting the everyday life of many people,[1] and its prevalence is higher among subjects aged 70–74 years. The percentage of people aged over 60 years in Europe is currently 22% and is expected to reach 27% by 2020. According to Eurostat, the increase in Greece in the percentage of subjects aged 65–79 years is the highest of all the members of the European Union (EU).[2]

Total knee arthroplasty (TKA) is the most effective surgical procedure for the treatment of advanced OA of the knee when conservative treatment has failed to improve the quality of life of patients. TKA provides most patients with an adequate range of motion of the knee,[3] improves limitations in activity,[4,5] and reduces arthritic knee pain.[6] Most patients undergoing TKA have good clinical results in the reduction of pain,[7] but functional problems may persist. Several studies have shown that people continue to have difficulties with walking and other physical activities following knee replacement surgery. People with a knee replacement were reported to have a lower maximal walking speed and to negotiate stairs more slowly than control subjects even beyond 1 year after surgery.[8,9]

Quadriceps muscle weakness has been identified in the development and progression of OA of the knee,[10] and

is also related to functional mobility in patients following TKA.[9,11] It has been shown to play an important role in mediating the recovery of functional abilities for patients after TKA,[12] as it is related more strongly to the functional outcome than range of knee flexion or bodily pain.[13]

Quadriceps strength in the operated limb decreases drastically immediately after the surgery, with a reduction of approximately 60% observed from pre-operative strength.[12] It then gradually increases to a level comparable with preoperative strength levels and plateaus at 6 to 12 months after surgery.[13]

Asymmetry in peak isometric knee extensor torque between the operated and contralateral limbs has been shown to persist 6 months,[14] and up to one year[15] after surgery. Differences of 21% to 42% has been reported in knee extensor torque for the operated knee compared with the contralateral knee at 3 to 6 months after surgery.[13,16,17] Even at 1 to 2 years after knee replacement surgery, a difference of 12% to 29% between the knee extensor muscles was still evident.[8,18] In isokinetic measurements following TKA, individuals have a strength deficit of 20%[18–23] or more. Similar deficits, although not so consistent[15] have been reported for knee flexor muscle strength.[8,21,24] Patients remain considerably weaker than healthy age-matched peers[13,17,25] with large quadriceps strength deficits, ranging from 19% to 44%.[16,17] Knee extensor muscle strength has been reported to remain 35% lower in people with knee replacement than in age-matched control subjects, even at 13 years after surgery.[19]

Currently, evidence is limited as to why patients who undergo TKA cannot resolve their muscle atrophy in the operated limb.[15] Functional limitation may persist 6 months to one year after surgery,[7,8] and levels of physical activity do not change after TKA.[26]

Although some researchers use isokinetic contractions of the muscles of the knee in TKA patients,[14,15,18,21–23] in the majority of reports the assessment of quadriceps muscle strength was determined by measuring the maximum isometric torque (maximal voluntary isometric contraction, MVIC) at 75° of knee flexion.[7,15,27–29] Knee extensor strength is an impairment-based measure that is associated with functional performance, and performance-based measures must be dynamic, requiring knee muscle activity across a broad range of joint angles and contraction types. Assessing a muscle group isokinetically may provide better insight into the factors affecting functional ability. Measurement of muscle strength in patients after TKA is necessary for a more comprehensive understanding of the factors that contribute to the persistent functional deficits.[30]

In this study, the isokinetic quadriceps muscle strength at 60°/s and 180°/s was investigated, in order to analyse knee muscle strength throughout a range of motion (ROM) of the knee from 0° to 105°. The purpose was to explore the correlation between isokinetic knee concentric muscular testing and three functional tests, the Timed "Up & Go" test (TUG), the 6-minute walking test (6MWT) and the Stair-Climbing test (SCT), in patients who had undergone TKA at least 12 months earlier. Assessment was made approximately 12 months after TKA because quadriceps strength exhibits a plateau in the postoperative period.[8,9] The authors hypothesized that (a) patients who undergo TKA will exhibit asymmetry in peak isokinetic knee muscle torque between the operated and the contralateral limb, one year after surgery; (b) peak torque of the muscles of the operated knee, produced across two main isokinetic velocities (normalized to body weight), will be significantly correlated with performance in lower extremity functional tests (e.g., difficulty in walking, stair ascending, etc.).

MATERIAL AND METHOD

Subjects

The study subjects were 15 individuals who had undergone primary unilateral TKA at least one year earlier for end stage OA of the knee (mean age: 70±6.3 years; mean height: 158.4±8.19 m; mean body mass: 91.1±16.1 kg), who participated voluntarily (tab. 1). Participants were excluded if they reported pain greater than 4 on a scale of 1 to 10 in the operated limb during everyday activities, or had any other lower extremity pathology that would cause limited functionality. During the post-operative period, all the subjects had followed a standardized rehabilitation protocol.[13] The study protocol was approved by the Ethical Committee of the Department of Physiotherapy of the Technological Educational Institute of Central Greece. All the subjects received a clear explanation of the study, including the risks and benefits of participation and their written informed consent was obtained prior to testing.

Quantitative clinical measurements were recorded at the evaluation, including height, weight, bilateral knee muscle strength, TUG, SCT, and 6MWT.

Testing procedures

Prior to testing the age, height and mass of the subjects were recorded. Height was measured barefoot using a portable stadiometer (Seca 213, Ecomed Trading, Australia) and recorded to the nearest 0.01 m (1 cm). Body mass was recorded to the nearest 0.01 kg, using electronic digital scales (BF-522, Tanita Corporation, Japan). Isokinetic strength testing was conducted in the biomechanics laboratory of the university on a Biodex System 3 pro (Biodex Systems, Inc, Corporation, Shirley, NY) isokinetic dynamometer.

Table 1. Physical characteristics of the study participants at least one year after total knee arthroplasty.

Characteristics (n=15)	Descriptive statistics									
	Women (n=11)					Men (n=4)				
	Range	Min	Max	Mean	SD	Range	Min	Max	Mean	SD
Age (years)	23.0	56.0	79.0	69.18	6.6	12.0	66.0	78.0	72.25	5.679
Body weight (kg)	51.6	68.4	120.0	87.755	15.7210	32.9	86.0	118.9	100.4	15.3586
Body height (cm)	19.0	148.5	167.5	155.0	6.4537	9.0	164.5	173.5	167.75	3.9686
6MWT (m)	240.0	120.0	360.0	266.45	67.476	95.0	275.0	370.0	308.75	43.661
TUG (s)	10.36	8.84	19.2	11.7518	3.11175	4.85	7.1	11.95	9.3825	2.01219
SCT (s)	63.95	18.05	82.0	39.0782	17.8722	16.16	17.39	33.55	25.635	7.38211

6MWT: 6 minute walking test, TUG: Timed "up & go" test, SCT: Stair-Climbing test, Min: Minimum, Max: Maximum

Functional performance measures

Measures of functional performance included TUG, SCT and 6MWT. The TUG measures the time needed to rise from an arm chair (seat height, 46 cm), walk 3 m, turn, and return to the sitting position in the same chair, without physical assistance.[13] The TUG has previously been shown to have high intra- and inter-rater reliability.[31,32] The SCT, a practically higher level of activity, measures the time to ascend and descend a flight of stairs and has been shown to correlate with the TUG and to have good reliability.[33–35] The 6MWT measures the total distance walked in meters over 6 minutes. This test has been used extensively to measure endurance and has been validated as a measure of functional performance following knee arthroplasty.[1] It also has been shown to have good reliability.[36]

Isokinetic strength assessment

All the patients were able to complete the isokinetic contractions across the two angular velocities (n=15). Knee extensor and flexor strength was performed on a Biodex System 3 pro (Biodex Systems, Inc, Corporation, Shirley, NY) isokinetic dynamometer at velocities of 60°/s and 180°/s. These muscle groups were selected for analysis because of their significant contribution to functional activities. Muscle strength was operationally defined as the peak isokinetic torque produced during a set of volitional contractions on a Biodex dynamometer. Concentric torque was assessed at two angular velocities: 60°/s and 180°/s. Contractions were performed through a range of 0°–105° (full extension defined as 0°). Testing order progressed from the slowest to the highest speeds.

The patients were tested in the seated position with hip flexion of approximately 115° and with stabilisation straps applied to the trunk, waist and thigh. The resistance pad was placed at a level of 2.5 cm proximal to the medial malleolus.[37] The subject was secured to the seat and then completed a warm-up of three submaximal repetitions at each testing velocity, with a 60-second rest interval between each set. Following this, the subject completed five maximal repetitions at 60°/s, followed by a 60-second recovery, and then ten maximal repetitions at 180°/s. The same procedure was repeated for each leg. All the patients underwent testing of the noninvolved limb first. The range of motion during testing was set from 0° to 105° of knee flexion, and the limbs were gravity compensated. A rest of 30 seconds between test bouts was available to the subject to minimize fatigue. The subjects held on to the seat handles during testing. To ensure maximal effort, verbal encouragement was provided. The verbal commands were standardized during testing. For the isokinetic contractions, the subjects were instructed to straighten and bend their knee, "as hard and as fast as possible".

Statistical analysis

For each isokinetic angular velocity, the peak torque (Nm) generated during each repetition, for the knee extensors and flexors separately, was calculated within the Biodex software. The use of peak torque to measure isokinetic strength is the standard presentation of isokinetic muscle strength data.[34] The maximal peak torque value within each set of the repetitions was used for analysis.

All statistical analyses were computed using the Statistics Package for Social Sciences (SPSS, version 17.0; IBM Corporation, New York, USA).

In order to study the differences between the mean values of the knee extension/flexion maximal peak torque at 60°/s and 180°/s measurements of the involved and uninvolved knees, the parametric t-test for paired design was used, since the Kolmogorov-Smirnov (KS) test revealed that the variables approximated normal distribution. An alpha level of $p \leq 0.05$ was chosen as the criterion for statistical significance.

Correlation coefficients were calculated to determine the associations between the three functional performance measures (TUG, SCT, 6MWT) and the two strength measures (isokinetic results at the two angular velocities) for the TKA limb.

Linear regression (LR) analysis was applied to study the effect of knee extensor and flexor strength (knee extension maximal peak torque at 60°/s and 180°/s, knee flexion maximal peak torque at 60°/s and 180°/s) on the three functional tests, 6MWT, TUG and SCT. Regression analysis was performed for the TKA limb, to determine

which, if any, measurements of power significantly improved the predictability of performance in each of the three functional tests. The level of statistical significance was set at 0.05.

Limitations of the study

The present study had certain limitations. Since outcome was examined only 12 months post-operatively, the results cannot be generalized to predict relationships beyond this time point and causal relationships or associations over time cannot be speculated. The study population consisted of people who had undergone successful TKA, who were relatively healthy and mobile and who were living in the rural area around the city of Lamia, Greece. It is impossible to extrapolate the association between function and strength in this group to that of people with a different (e.g., urban) lifestyle. This may be a factor limiting the external validity of the study.

In addition, comparison with the non-operated leg should be considered carefully. Many patients with unilateral TKA eventually go on to have the other knee joint replaced because of degenerative changes and pain. Approximately 40% of patients with unilateral TKA progress to a TKA in their non-operated leg within 10 years;[41] hence, the uninvolved knee should not be considered as a typically unimpaired joint, as it may be in at least the early stages of OA. The gamut of OA is wide and can cause considerable variability in the findings, especially with a relatively limited sample size such as in this study.

RESULTS

Strength testing

Table 2 summarizes the descriptive statistics of the variables examined. Parametric testing revealed no significant difference between the mean values of knee extension

Table 2. Functional testing of knees at least one year after total knee arthroplasty (involved/uninvolved knees) (n=15).

		Descriptive statistics			t-test		
		Involved	Uninvolved	Total	t	df	p
Knee extension maximal peak torque at 60°/s (Nm)	N	15.0	15.0	30.0	-1.570	14	0.139
	M	61.8	70.3	66.0			
	SD	19.6	26.3	23.2			
	Mdn	60.9	62.2	61.0			
	Min	35.0	31.8	31.8			
	Max	96.7	133.0	133.0			
Knee extension maximal peak torque at 180°/s (Nm)	N	15.0	15.0	30.0	-2.356	14	0.034
	M	40.4	46.4	43.4			
	SD	14.2	15.5	14.9			
	Mdn	41.7	45.2	43.0			
	Min	17.4	26.2	17.4			
	Max	65.2	76.6	76.6			
Knee flexion maximal peak torque at 60°/s (Nm)	N	15.0	15.0	30.0	-1.622	14	0.127
	M	33.8	38.5	36.1			
	SD	12.6	15.6	14.1			
	Mdn	34.5	39.9	39.0			
	Min	13.3	15.0	13.3			
	Max	61.1	75.1	75.1			
Knee flexion maximal peak torque at 180°/s (Nm)	N	15.0	15.0	30.0	-0.624	14	0.543
	M	23.9	24.9	24.4			
	SD	9.7	9.3	9.3			
	Mdn	26.3	25.3	25.3			
	Min	3.9	4.1	3.9			
	Max	40.6	42.9	42.9			

M: Mean, SD: Standard deviation, Mdn: Median, Min: Minimum, Max: Maximum

maximal peak torque at 60°/s of the involved and uninvolved knees (tab. 2).

A statistically significant difference was demonstrated between the mean values of knee extension maximal peak torque at 180°/s of the involved and uninvolved knees (tab. 2).

Analysis revealed no significant difference in knee flexion maximal peak torque at 60°/s and 180°/s, between the mean values of the involved and uninvolved knees (tab. 2).

Correlation between functional knee test scores and isokinetic testing

In addition to the independent covariates (knee extensor and flexor strength), demographic variables were included in the stepwise analysis to take into account potential sources of variation not explained by the main covariates of the study. The dependent variables (i.e. the functional knee test scores) were initially checked for normal distribution by KS testing.

6-minute walk test (6MWT)

The results of the four models using the 6MWT as dependent variable are summarized in table 3. In the first model, the parametric Pearson's correlation coefficient revealed a moderate positive association between 6MWT and knee extension peak torque at 60°/s, r(15)=0.525, p=0.044. LR analysis indicated only knee extension maximal peak torque at 60°/s as a significant predictor, explaining 27.6% of the variance in 6MWT (R2=0.276, F(1,13)=4.951, p=0.044). The estimated parameter for knee extension maximal peak torque at 60°/s (t=2.225, p=0.044) (tab. 3) indicates that for every unit increase in the knee extension maximal peak torque at 60°/s, the 6MWT score will increase by 1.703 units.

In the second model, a moderate positive association was demonstrated between 6MWT and knee extension maximal peak torque at 180°/s, r(15)=0.647, p=0.009 (tab. 3). Only knee extension maximal peak torque at 180°/s was a significant predictor, explaining 41.8% of the variance in 6MWT (R2=0.418, F(1,13)=9.350, p=0.009). For every unit increase in the knee extension maximal peak torque at 180°/s, the 6MWT score will increase by 2.898 units (t=3.058, p=0.009) (tab. 3).

In the third model, a moderate positive association was found between 6MWT and knee flexion maximal peak torque at 60°/s, r(15)=0.569, p=0.027 (tab. 3) which was a significant predictor explaining 32.4% of the variance in 6MWT (R2=0.324, F(1,13)=6.217, p=0.027). For every unit increase in the knee flexion maximal peak torque at 60°/s, the 6MWT score will increase by 2.861 units (t=2.493, p=0.027) (tab. 3).

In the fourth model, a moderate positive association was demonstrated between 6MWT and knee flexion maximal peak torque at 180°/s, r(15)=0.615, p=0.015 (tab. 3), which was a significant predictor, explaining 37.9% of the variance in 6MWT (R2=0.379, F(1,13)=7.922, p=0.015). For every unit increase in knee flexion maximal peak torque at 180°/s, the 6MWT score will increase by 4.036 units (t=4.036, p=0.015) (tab. 3).

Table 3. Linear regression models for 6 minute walking test (6MWT) at least one year after total knee arthroplasty (n=15).

	F	p	B	SE	t	p
Constant	4.951	0.044	172.555	49.439	3.490	0.004
Knee extension maximal peak torque at 60°/s			1.703	0.765	2.225	0.044
Notes: R=0.525, p=0.044, R2=0.276						
Constant	9.350	0.009	160.526	40.469	3.967	0.002
Knee extension maximal peak torque at 180°/s			2.898	0.948	3.058	0.009
Notes: R=0.647, p=0.009, R2=0.418						
Constant	6.217	0.027	181.127	41.197	4.397	0.001
Knee flexion maximal peak torque at 60°/s			2.861	1.147	2.493	0.027
Notes: R=0.569, p=0.027, R2=0.324						
Constant	7.922	0.015	181.336	36.783	4.930	<0.001
Knee flexion maximal peak torque at 180°/s			4.036	1.434	2.815	0.015
Notes: R=0.615, p=0.015, R2=0.379						

Timed "Up-and-Go" test (TUG)

The results of the four models using TUG as dependent variable are summarized in table 4.

In the first model, a moderate negative association was found between TUG and knee extension maximal peak torque at 60°/s, r(15)=-0.646, p=0.009 (tab. 4), which was a significant predictor, explaining 41.7% of the variance in TUG (R2=0.417, F(1,13)=9.298, p=0.009). For every unit increase in the knee extension maximal peak torque at 60°/s, the TUG score will decrease by 0.099 units (t=-3.049, p=0.009) (tab. 4).

In the second model, a strong negative association was revealed between TUG and knee extension maximal peak torque at 180°/s, r(15)=-0.714, p=0.003 (tab. 4), which was a significant predictor, explaining 51.0% of the variance in TUG (R2=0.510, F(1,13)=13.533, p=0.003). For every unit increase in knee extension maximal peak torque at 180°/s, the TUG score will decrease by 0.151 units (t=-3.679, p=0.003) (tab. 4).

In the third model, no association was found between TUG and knee flexion maximal peak torque at 60°/s, r(15)= -0.246, p=0.378 (tab. 4).

In the fourth model, no association was found between TUG and knee flexion maximal peak torque at 60°/s, r(15)= -0.445, p=0.096 (tab. 4).

Stair Climbing test

The results of the four models using the SCT as dependent variable are summarized in table 5.

In the first model, a moderate negative association was found between SCT and knee extension maximal peak torque at 60°/s, r(15)=-0.549, p=0.034 (tab. 5), which was a significant predictor, explaining 30.1% of the variance in SCT (R2=0.301, F(1,13)=5.609, p=0.034). For every unit, increase in the knee extension maximal peak torque at 60°/s, the SCT score will decrease by 0.467 units (t=-2.368, p=0.034) (tab. 5).

In the second model, a moderate negative association was demonstrated between SCT and knee extension maximal peak torque at 180°/s, r(15)=-0.589, p=0.021 (tab. 5), which was a significant predictor, explaining 34.7% of the variance in SCT (R2=0.347, F(1,13)=6.907, p=0.021). For every unit increase in the knee extension maximal peak torque at 180°/s, the SCT score will decrease by 0.692 units (t=-2.628, p=0.021) (tab. 5).

In the third model, no association was found between SCT and knee flexion maximal peak torque at 60°/s, r(15)= -0.343, p=0.211 (tab. 5).

In the fourth model, no association was found between SCT and knee flexion maximal peak torque at 60°/s, r(15)= -0.345, p=0.208 (tab. 5).

Table 4. Linear regression models for the Timed "up & go" test (TUG) at least one year after total knee arthroplasty (n=15).

	F	p	B	SE	t	p
Constant	9.298	0.009	17.214	2.090	8.235	<0.001
Knee extension maximal peak torque at 60°/s			-0.099	0.032	-3.049	0.009
Notes: R=-0.646, p=0.009, R2=0.417						
Constant	13.533	0.003	17.218	1.750	9.838	<0.001
Knee extension maximal peak torque at 180°/s			-0.151	0.041	-3.679	0.003
Notes: R=-0.714, p=0.003, R2=0.510						

Table 5. Linear regression models for the Stair-Climbing test (SCT) at least one year after total knee arthroplasty (n=15).

	F	p	B	SE	t	p
Constant	5.609	0.034	64.337	12.737	5.041	<0.001
Knee extension maximal peak torque at 60°/s			-0.467	0.197	-2.368	0.034
Notes: R=-0.549, p=0.034, R2=0.301						
Constant	6.907	0.021	63.493	11.249	5.644	<0.001
Knee extension maximal peak torque at 180°/s			-0.692	0.263	-2.628	0.021
Notes: R=-0.589, p=0.021, R2=0.347						

DISCUSSION

The authors hypothesized that patients who have undergone TKA will exhibit asymmetry in peak isokinetic knee muscle torque between the operated and contralateral limbs, one year after surgery. This hypothesis was not completely supported by the study data.

The results of this study showed that 12 months after unilateral TKA, the mean peak torque of the extensor muscles in the operated leg was not significantly weaker than that of the muscles in the non-operated leg, at 60°/s. This contrasts with the reports of other investigators who consistently found significant differences in both isometric[13–15] and isokinetic measurements.[21] The box plot in figure 1 shows that the distribution of the peak torque value of the extensors at 60°/sec is concentrated higher in the uninvolved than in the involved knee, although not to a statistically significant degree. This lack of significance may be attributed to the small number of participants in the present study. The absence of significant side-to-side differences between the operated and the non-operated leg might be attributable to the everyday activities of the subjects. Some authors[11] reported that weakness of the knee extensor muscles in people after TKA was closely associated with mobility limitations. The rural lifestyle of the subjects in this study may have forced them to participate in more activities than the average urban patient. It is therefore an open question whether the lifestyle of the patients and their everyday activities play a greater role in the recovery of muscle strength than a standard rehabilitation programme.

At the velocity of 180°/s, the mean maximal peak torque of the extensor muscles of the operated leg was statistically significantly weaker than that of the non-operated leg. Researchers[19] have reported that the muscle strength remains 35% lower in people with TKA than in age-matched subjects, even 13 years after surgery. This muscle group should receive attention during assessment and rehabilitation of degenerative knee joint problems, at this particular velocity.

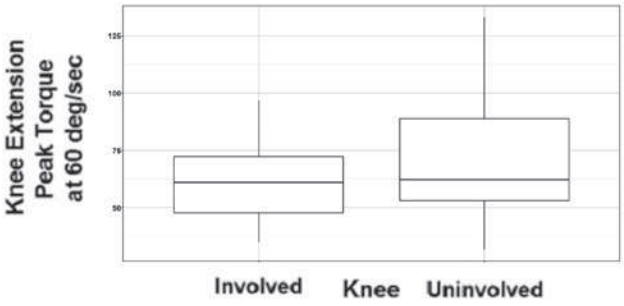

Figure 1. Boxplot of knee extension peak torque (involved/uninvolved knees) at 60°/s one year after unilateral total knee arthroplasty (n=15).

The results of this study showed that 12 months after TKA, the flexor muscles of the operated leg at both 60°/s and 180°/s, showed no statistically significant differences between the mean maximal peak torques of the muscles. A comparison of the results of the present study with previous reports is difficult because to the authors' knowledge only one study[21] calculated the muscle strength deficit for the flexor muscles at 60°/s, finding knee flexor torque deficit (13%) an average of 10 months after TKA. The only data on flexor muscles in the operated leg, for the velocity of 180°/s (21.5±9.80), were reported by Huang and colleagues.[19] Before this muscle group is given more attention in rehabilitation, further studies need to be made to determine a better approximation of the differences between the two limbs.

It was hypothesized that peak torque of the operated knee produced across two main isokinetic velocities would be significantly correlated with performance in functional tests of the legs. LR analysis was used to study the effect of knee extensor and flexor strength (specifically, knee extension maximal peak torque at 60°/s and 180°/s, and knee flexion maximal peak torque at 60°/s and 180°/s) on the three functional tests 6MWT, TUG, and SCT. The findings demonstrate that measurements of maximal peak knee flexor and extensor torque across two isokinetic velocities are correlated with functional performance tests 12 months after TKA.

SCT and TUG are time-based measures where a better performance is equivalent to a lower score (i.e., the time taken); therefore, a negative correlation coefficient with peak torque would suggest that greater torque is related to better SCT and TUG performance. Conversely, 6MWT is the distance covered in 6 minutes, a lower score is an indication of poorer performance, and therefore a positive correlation with peak torque would suggest that the greater the torque the better the 6MWT distance.

6-minute walk test (6MWT)

Maximal knee extensor peak torque at 60°/s and 180°/s was positively associated with the walking ability of the patients. Greater quadriceps strength resulted in a significantly longer distance travelled during the 6MWT test. Isokinetic strength of the knee extensor muscles was closely related to the functional variables of our model and LR indicated that the extension peak torque at 60°/s explains 27.6% of

the variance of the 6MWT whilst maximal knee extension peak torque at 180°/s explains 41.8% of the variance of the 6MWT.

A patient with a strong quadriceps will walk further distance in the 6MWT. In the clinical environment where patients may do only a limited number of exercises, to be able to target the exercises with the greatest impact on functional activities is a key towards a successful rehabilitation program. The information provided by this study illustrates the extent of the importance of the quadriceps strength and in particular shows that the higher speed (180°/s) quadriceps results appear more important for the ability to walk than the lower speed.

The findings of the current study support previous reports that measurement of leg extensor power was associated with functional performance in patients after TKA.[38] The association between maximal isometric knee extensions and function in that study[38] was similar (i.e., measurement of function compared with normalized knee extension strength r=0.51, p=0.001) with that in the present study (r=0.525, p=0.647).

Leg extension power is thought to be an important determinant of walking speed after TKA.[39] A strong association has been reported between quadriceps strength in the operated limb after 12 months and the 6MWT test (r=0.902, p<0.05),[9] but Yoshida and colleagues[9,15,40] measured quadriceps strength with an isometric contraction at 75° of knee flexion. A dynamic strength measurement in this study revealed a moderate association between 6MWT and maximal knee extension peak torque at 60°/s (r=0.525, p=0.044).

Positive correlation was found between the 6MWT result and the flexor strength measures at both 60°/s and 180°/s, indicating that individuals who produced higher levels of peak power walked further during the test.

Patients after TKA need strengthening and reeducation in the use of not only the knee extensors but also the knee flexors, a practice not widespread among clinicians. Isokinetic strength of the knee flexor muscles was closely related to 6MWT, and LR indicated that the flexion peak torque at 60°/s explains 32.4% of the variance and maximal knee flexion peak torque at 180°/s explains 37.9% of the variance in 6MWT.

To the knowledge of the authors, this is the first time LR has been applied to the relationship between the 6MWT test and the flexor strength measures. In the event that a patient wants to walk more after TKA, the rehabilitation program should concentrate not only on the quadriceps, but also on the flexor muscles in order to achieve its goals.

Timed Up-and-Go and Stair Climbing test

Negative correlation was exhibited between the torque measurements and the functional assessment according to TUG and SCT, showing that individuals who produced lower levels of peak torque needed more time to complete these two tests.

Decreased lower-limb muscle power is one of the factors underlying mobility limitations in older adults. Some investigators[13] have reported that quadriceps strength was correlated with functional performance at all testing sessions from pre-surgery until 6 months after TKA, at which point a plateau in measurement outcome appears. Others[11] reported that weakness of the knee extensor muscles in people with TKA was closely associated with mobility limitations, especially in stair-climbing tasks and the TUG test.

Leg extension power is reported to be an important determinant of stair-ascending time after knee replacement.[39] It has also been reported[21] that torque deficits are associated with longer stair-ascending and stair-descending times, but not with maximal walking speed.

The above reports are all in partial agreement with the results of the present study, which showed that in subjects recovering from TKA a large strength deficit in knee extensors is associated with limitations in stair climbing and TUG and with reduced walking speed. It would appear that because walking is a common functional task, the non-operated leg may be able to compensate partially for problems in the operated leg. In order, however, to perform more-demanding functional tasks, such as stair ascending and descending, a person needs more power and force production in the knee extensor muscles.

No association was found between performance on TUG and SCT and the knee flexors at either isokinetic speed.

In conclusion, patients who have undergone unilateral TKA do not demonstrate significant functional differences between the legs 12 months after the operation. The only difference between the mean maximal peak torque of the two knees was in the extensor muscles at a velocity of 180°/s, indicating that the rehabilitation programme of a more active lifestyle for patients should be adapted accordingly.

After TKA, maximal knee extension strength was closely associated with the performance on functional tests. Patients need strengthening of not only the knee extensors but also the knee flexors in order to be able to walk more. Exercises for knee extensors at a higher speed appear

important in the ability to walk and to negotiate stairs effectively. Measurement of knee strength may be a useful tool for clinicians when assessing and setting milestones during rehabilitation. Functional tests should be considered when evaluating gait and function, as well as the design of the rehabilitation program following TKA.

ΠΕΡΙΛΗΨΗ

Σχέση μεταξύ μέσης μέγιστης ισοκινητικής ροπής και λειτουργικής απόδοσης, 12 μήνες μετά από ολική αρθροπλαστική γόνατος

Ι. ΠΟΥΛΗΣ,[1] Κ. ΒΑΣΣΗΣ,[1] Ε. ΚΑΠΡΕΛΗ,[1] Τ. ΧΑΔΟΣ,[2] Σ. ΧΑΔΟΣ,[3] Α. ΚΑΝΕΛΛΟΠΟΥΛΟΣ[1]

[1]Τμήμα Φυσικοθεραπείας, Τεχνολογικό Εκπαιδευτικό Ίδρυμα Στερεάς Ελλάδας, Λαμία,

[2]Αριστοτέλειο Πανεπιστήμιο Θεσσαλονίκης, Θεσσαλονίκη, [3]Γενικό Νοσοκομείο Λαμίας, Λαμία

Αρχεία Ελληνικής Ιατρικής 2017, 34(3):363–372

ΣΚΟΠΟΣ Μέτρηση της συσχέτισης μεταξύ της μέσης μέγιστης ισοκινητικής ροπής των μυών του γόνατος και της λειτουργικής απόδοσης 12 μήνες μετά τη μονόπλευρη ολική αρθροπλαστική γόνατος (ΟΑΓ). **ΥΛΙΚΟ-ΜΕΘΟΔΟΣ** Δεκαπέντε ασθενείς που υποβλήθηκαν σε μονόπλευρη ΟΑΓ συμμετείχαν στη μελέτη. Οι μέσες μέγιστες ισοκινητικές ροπές τετρακέφαλου και οπίσθιων μηριαίων αξιολογήθηκαν, χρησιμοποιώντας ισοκινητικό δυναμόμετρο στις γωνιακές ταχύτητες των 60°/s και 180°/s. Η λειτουργική απόδοση αξιολογήθηκε, εφαρμόζοντας το Stair-Climbing test (SCT), το Timed Up-and-Go test (TUG) και το 6-minute walk test (6MWT). **ΑΠΟΤΕΛΕΣΜΑΤΑ** Η μέση μέγιστη ροπή των μυών του γόνατος στις δύο γωνιακές ταχύτητες συσχετίστηκε με τα λειτουργικά αποτελέσματα απόδοσης των ασθενών. Η λειτουργική απόδοση ήταν στατιστικώς σημαντικά συσχετιζόμενη με τη μέση μέγιστη ροπή των εκτεινόντων μυών και στις δύο ισοκινητικές ταχύτητες. Το 6MWT συσχετίστηκε σημαντικά με τη μέση μέγιστη ροπή των καμπτήρων μυών και στις δύο γωνιακές ταχύτητες. Η μόνη στατιστικά σημαντική διαφορά μεταξύ της μέσης μέγιστης ροπής των δύο άκρων αφορούσε στους εκτείνοντες στη γωνιακή ταχύτητα των 180°/s. Σε αυτή την ταχύτητα, η μέση μέγιστη ροπή των εκτεινόντων μυών του χειρουργημένου σκέλους ήταν σημαντικά ασθενέστερη απ' ό,τι στο μη χειρουργημένο πόδι. Οι καμπτήρες του χειρουργημένου σκέλους, τόσο στις 60°/s όσο και στις 180°/s, δεν είχαν στατιστικά σημαντικές διαφορές στη μέση μέγιστη ροπή τους σε σχέση με το υγιές σκέλος. **ΣΥΜΠΕΡΑΣΜΑΤΑ** Τα αποτελέσματα της ροπής των εκτεινόντων μυών του γόνατος μπορεί να αποτελούν ένα χρήσιμο εργαλείο για τους κλινικούς κατά την αξιολόγηση και τον καθορισμό στόχων κατά τη διάρκεια της αποκατάστασης.

Λέξεις ευρετηρίου: Αντικατάσταση γόνατος, Αποτελέσματα αξιολόγησης, Δύναμη, Λειτουργική απόδοση

References

1. TSONGA T, KAPETANAKIS S, PAPADOPOULOS C, PAPATHANASIOU J, MOURGIAS N, GEORGIOU N ET AL. Evaluation of improvement in quality of life and physical activity after total knee arthroplasty in Greek elderly women. *Open Orthop J* 2011, 5:343–347
2. HELLENIC STATISTICAL AUTHORITY. (2004) Statistical Greek Bureau 2003
3. MISRA AN, SMITH RB, FIDDIAN NJ. Five year results of selective patellar resurfacing in cruciate sparing total knee replacements. *Knee* 2003, 10:199–203
4. FINCH E, WALSH M, THOMAS SG, WOODHOUSE LJ. Functional ability perceived by individuals following total knee arthroplasty compared to age-matched individuals without knee disability. *J Orthop Sports Phys Ther* 1998, 27:255–263
5. HECK DA, ROBINSON RL, PARTRIDGE CM, LUBITZ RM, FREUND DA. Patient outcomes after knee replacement. *Clin Orthop Relat Res* 1998, 356:93–110
6. KÖNIG A, WALTHER M, KIRSCHNER S, GOHLKE F. Balance sheets of knee and functional scores 5 years after total knee arthroplasty for osteoarthritis: A source for patient information. *J Arthroplasty* 2000, 15:289–294
7. BADE MJ, KOHRT WM, STEVENS-LAPSLEY JE. Outcomes before and after total knee arthroplasty compared to healthy adults. *J Orthop Sports Phys Ther* 2010, 40:559–567
8. WALSH M, WOODHOUSE LJ, THOMAS SG, FINCH E. Physical impairments and functional limitations: A comparison of individuals 1 year after total knee arthroplasty with control subjects. *Phys Ther* 1998, 78:248–258
9. YOSHIDA Y, MIZNER RL, RAMSEY DK, SNYDER-MACKLER L. Examining outcomes from total knee arthroplasty and the relationship between quadriceps strength and knee function over time. *Clin Biomech (Bristol, Avon)* 2008, 23:320–328
10. SLEMENDA C, HEILMAN DK, BRANDT KD, KATZ BP, MAZZUCA SA, BRAUNSTEIN EM ET AL. Reduced quadriceps strength relative to body weight: A risk factor for knee osteoarthritis in women? *Arthritis Rheum* 1998, 41:1951–1959

11. MIZNER RL, SNYDER-MACKLER L. Altered loading during walking and sit-to-stand is affected by quadriceps weakness after total knee arthroplasty. *J Orthop Res* 2005, 23:1083–1090
12. MIZNER RL, PETTERSON SC, STEVENS JE, VANDENBORNE K, SNYDER-MACKLER L. Early quadriceps strength loss after total knee arthroplasty. The contributions of muscle atrophy and failure of voluntary muscle activation. *J Bone Joint Surg Am* 2005, 87:1047–1053
13. MIZNER RL, PETTERSON SC, SNYDER-MACKLER L. Quadriceps strength and the time course of functional recovery after total knee arthroplasty. *J Orthop Sports Phys Ther* 2005, 35:424–436
14. MAFFIULETTI NA, BIZZINI M, WIDLER K, MUNZINGER U. Asymmetry in quadriceps rate of force development as a functional outcome measure in TKA. *Clin Orthop Relat Res* 2010, 468:191–198
15. YOSHIDA Y, MIZNER RL, SNYDER-MACKLER L. Association between long-term quadriceps weakness and early walking muscle co-contraction after total knee arthroplasty. *Knee* 2013, 20:426–431
16. GAPEYEVA H, BUHT N, PETERSON K, ERELINE J, HAVIKO T, PÄÄSUKE M. Quadriceps femoris muscle voluntary isometric force production and relaxation characteristics before and 6 months after unilateral total knee arthroplasty in women. *Knee Surg Sports Traumatol Arthrosc* 2007, 15:202–211
17. MEIER W, MIZNER RL, MARCUS RL, DIBBLE LE, PETERS C, LASTAYO PC. Total knee arthroplasty: Muscle impairments, functional limitations, and recommended rehabilitation approaches. *J Orthop Sports Phys Ther* 2008, 38:246–256
18. ROSSI MD, BROWN LE, WHITEHURST M. Knee extensor and flexor torque characteristics before and after unilateral total knee arthroplasty. *Am J Phys Med Rehabil* 2006, 85:737–746
19. HUANG CH, CHENG CK, LEE YT, LEE KS. Muscle strength after successful total knee replacement: A 6- to 13-year follow up. *Clin Orthop Relat Res* 1996, 328:147–154
20. BERMAN AT, BOSACCO SJ, ISRAELITE C. Evaluation of total knee arthroplasty using isokinetic testing. *Clin Orthop Relat Res* 1991, 271:106–113
21. VALTONEN A, PÖYHÖNEN T, HEINONEN A, SIPILÄ S. Muscle deficits persist after unilateral knee replacement and have implications for rehabilitation. *Phys Ther* 2009, 89:1072–1079
22. ROSSI MD, BROWN LE, WHITEHURST M, CHARNI C, HANKINS J, TAYLOR CL. Comparison of knee extensor strength between limbs in individuals with bilateral total knee replacement. *Arch Phys Med Rehabil* 2002, 83:523–526
23. ROSSI MD, BROWN LE, WHITEHURST M. Knee extensor function before and 1 year after simultaneous bilateral total knee arthroplasty: Is there asymmetry between limbs? *Am J Orthop (Belle Mead NJ)* 2011, 40:29–33
24. LORENTZEN JS, PETERSEN MM, BROT C, MADSEN OR. Early changes in muscle strength after total knee arthroplasty. A 6-month follow-up of 30 knees. *Acta Orthop Scand* 1999, 70:176–179
25. SILVA M, SHEPHERD EF, JACKSON WO, PRATT JA, McCLUNG CD, SCHMALZRIED TP. Knee strength after total knee arthroplasty. *J Arthroplasty* 2003, 18:605–611
26. HARDING PA, HOLLAND AE, HINMAN RS, DELANY C. Physical activity perceptions and beliefs following total hip and knee arthroplasty: A qualitative study. *Physiother Theory Pract* 2015, 31:107–113
27. BOONSTRA MC, DE WAAL MALEFIJT MC, VERDONSCHOT N. How to quantify knee function after total knee arthroplasty? *Knee* 2008, 15:390–395
28. CHRISTIANSEN CL, STEVENS-LAPSLEY JE. Weight-bearing asymmetry in relation to measures of impairment and functional mobility for people with knee osteoarthritis. *Arch Phys Med Rehabil* 2010, 91:1524–1528
29. STEVENS-LAPSLEY JE, BALTER JE, KOHRT WM, ECKHOFF DG. Quadriceps and hamstrings muscle dysfunction after total knee arthroplasty. *Clin Orthop Relat Res* 2010, 468:2460–2468
30. MARMON AR, MILCAREK BI, SNYDER-MACKLER L. Associations between knee extensor power and functional performance in patients after total knee arthroplasty and normal controls without knee pain. *Int J Sports Phys Ther* 2014, 9:168–178
31. PODSIADLO D, RICHARDSON S. The timed "Up & Go": A test of basic functional mobility for frail elderly persons. *J Am Geriatr Soc* 1991, 39:142–148
32. PIVA SR, FITZGERALD GK, IRRGANG JJ, BOUZUBAR F, STARZ TW. Get up and go test in patients with knee osteoarthritis. *Arch Phys Med Rehabil* 2004, 85:284–289
33. KENNEDY DM, STRATFORD PW, WESSEL J, GOLLISH JD, PENNEY D. Assessing stability and change of four performance measures: A longitudinal study evaluating outcome following total hip and knee arthroplasty. *BMC Musculoskelet Disord* 2005, 6:3
34. LUND H, SONDERGAARD K, ZACHARIASSEN T, CHRISTENSEN R, BULOW P, HENRIKSEN M ET AL. Learning effect of isokinetic measurements in healthy subjects, and reliability and comparability of Biodex and Lido dynamometers. *Clin Physiol Funct Imaging* 2005, 25:75–82
35. MARTIN JA, BUCKWALTER JA. Aging and the pathogenesis of osteoarthritis-implications for cartilage repair. *Eur Cells Mater* 2002, 4(Suppl 1):7
36. ENRIGHT PL. The six-minute walk test. *Respir Care* 2003, 48:783–785
37. AMUNDSEN LR. *Muscle strength testing: Instrumented and non-instrumented systems.* Churchill Livingstone, New York, 1990
38. AALUND PK, LARSEN K, HANSEN TB, BANDHOLM T. Normalized knee-extension strength or leg-press power after fast-track total knee arthroplasty: which measure is most closely associated with performance-based and self-reported function? *Arch Phys Med Rehabil* 2013, 94:384–390
39. LAMB SE, FROST H. Recovery of mobility after knee arthroplasty: Expected rates and influencing factors. *J Arthroplasty* 2003, 18:575–582
40. YOSHIDA Y, ZENI J, SNYDER-MACKLER L. Do patients achieve normal gait patterns 3 years after total knee arthroplasty? *J Orthop Sports Phys Ther* 2012, 42:1039–1049
41. RITTER MA, CARR KD, KEATING EM, FARIS PM. Long-term outcomes of contralateral knees after unilateral total knee arthroplasty for osteoarthritis. *J Arthroplasty* 1994, 9:347–349

Corresponding author:

K. Vassis, Department of Physical Therapy, Technological Educational Institute of Central Greece, 3rd km Old National Road Lamia-Athens, GR-351 00 Lamia, Greece
e-mail: konstantinosvass@gmail.com