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Impact of Kinesiotherapy Rehabilitation on Quadriceps Femoris Muscle Strength and Functionality in Total Hip Arthroplasty Patients

Impacto de la Rehabilitación con Kinesioterapia en la Fuerza y Funcionalidad del Músculo Cuádriceps Femoral en Pacientes con Artroplastía Total de Cadera

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SUMMARY: The objective was measure quadricep strength after Total Hip Arthroplasty (THA) and kinetic treatment and then determine its impact on the functional recovery of patients with hip osteoarthritis. A total of 79 (25 were male and 54 were female) patients with THA. Exclusion criteria were previous extra-system kinetic treatment, operated on for hip fracture, not completing the treatment. Maximum Isometric Strength (MIS), Time Up and Go (TUG), Modified Harris Hip Score. There was a significant increase in the MIS of the post-treatment operated knee extension in both men and women ($p < 0.0001$ SE = 0.43; $p < 0.0001$ SE = 1.22, respectively). In the TUG, the execution time was significantly lower post-treatment in both men and women ($p < 0.0001$ SE = 0.77; $p < 0.0001$ SE = 0.94, respectively). The final Harris score increased significantly post-treatment in male and female ($p < 0.0001$ SE = 2.90; $p < 0.0001$ SE = 1.96, respectively). the association between MIS and the Harris score, it was noted that, for a 1 kg increase in this measure compared to the initial assessment, the Harris score, after 12 weeks of treatment, increased by 0.179 points ($\beta = 0.179$; $p = 0.050$). The conclusions were Indicate an increase in knee extension MIS of the operated hip after treatment in both sexes. At the same time, functionality increased post-treatment in both male and female.

KEYWORDS: Total Hip Arthroplasty; Kinetic treatment; Functionality; Quadriceps femoris muscle.

INTRODUCTION

The hip joint is the joint between the head of femur and the acetabulum of the hip bone. It is a synovial joint, spheroid and multiaxial and therefore, very mobile. The hip joint is a robust and stable joint which allows, in standing, the transfer of the body's weight through the hip bones to the heads and neck of femur. The quadriceps femoris muscle is composed of rectus femoris muscle, vastus lateralis muscle, vastus intermedius muscle and vastus medialis muscle. Only the rectus femoris muscle has its origin in the hip bone. It is composed of straight head of rectus femoris and reflected head of rectus femoris. However, sometimes, it presents a third head of rectus femoris. The rectus femoris muscle is fusiform. The straight head of rectus femoris originates in the anterior superior iliac spine and reflected head of rectus femoris originates through a thin, flattened tendon in the supra-acetabular groove and the articular capsule of the hip joint. Due to the above, only the rectus femoris muscle acts in the hip joint.

Hip osteoarthritis (coxarthrosis) is among the most prevalent and disabling pathologies affecting older adults. An estimated 25 % of people living to age 85 have symptoms, and nearly 10 % undergo total hip replacement for severe coxarthrosis (Murphy *et al*., 2016).

Total hip arthroplasty (THA) is a surgical procedure that restores joint mobility. Suitable candidates for this surgical treatment are patients with decreased range of motion, pain, radiological signs of osteoarthritis, and who have not achieved results with conservative treatment (Slavkovic *et al*., 2012).

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Muscle strength decreases by 3 – 4 % each day during the first week after a period of immobilization. THA patients commonly experience a period of inactivity after surgery, possibly due to pain. On the other hand, adequate lower limb muscle strength, mainly in the abductor muscle, is required for successful rehabilitation. Hence, strength training should begin as soon as possible to reduce the influence of postoperative immobilization and the consequent deterioration of muscle mass (Umpierres *et al*., 2014).

Specifically, muscle mass and strength reductions are associated with decreased functionality, such as rising from a chair and/or walking. At the same time, age also impacts muscle morphology and functionality indices. Here, physical activity plays an important role in limiting this regression and, at the same time, improves multiple aspects of muscle health (Jacob *et al*., 2022).

In recent years, quadricep function has received considerable attention in patients with knee and hip osteoarthritis before and after joint replacement surgery (Lauermann *et al*., 2014). Quadricep strength is related to physical functioning in patients with total knee arthroplasty (TKA) and THA, indicating a strong predictive relationship with daily functional activities, such as walking or stairs (Gormaz-Veloso *et al*., 2022). In this context, maximum strength training is appropriate in the early postoperative phase of THA, focusing on the hip abductor musculature and the knee extensor muscles, so the increase in muscle strength of the lower limb would directly affect greater functionality (Husby *et al*., 2009).

In summary, the focus following TKA is on strengthening the quadriceps femoris and gluteus medius muscles, unlike THA, where the emphasis is on restoring the strength of the hip abductor group, primarily the gluteus medius, so quadricep strength is generally not quantified at either the beginning or end of the treatment plan. Therefore, this study aimed to measure quadricep strength after THA and kinetic treatment and then determine its impact on the functional recovery of patients with hip osteoarthritis.

METHOD

A retrospective, descriptive study was conducted between 2016 and 2019 in which patients who underwent THA surgery at the Hospital El Carmen (HEC) in Maipu-Chile, were selected. The following inclusion criteria were considered: unilateral THA, operated on at the HEC for osteoarthritis, having undergone kinetic treatment at the HEC. Exclusion criteria were previous extra-system kinetic treatment, operated on for hip fracture, not completing the treatment. Data from the initial and final assessments were recorded. The sessions lasted 1 hour, twice a week, focused on modulating pain, reducing volume increase, making the scar and soft tissues more flexible, achieving functional ranges in the hip and knee, increasing muscle strength and endurance (knee flexors and extensors and abductors, hip extensors and flexors), improving static and dynamic balance, re-educating gait phases, and improving the functionality of their activities of daily living (ADL). This study has been approved by the Scientific Ethics Committee of the Central Metropolitan Health Service (resolution no. 048975).

Measurements

Maximum Isometric Strength (MIS). The MIS measurement was performed in a quadriceps chair (HUR 3530®, Kokkola, Finland) and a dynamometer (HUR 9200®, Kokkola, Finland). The patient was seated with the knee joint in 90° flexion and was asked to perform a maximum knee extension contraction for 5 s. Three attempts were recorded, with the highest one being considered (Lauermann *et al*., 2014; Leporace *et al*., 2023).

Time Up and Go (TUG). The patient was seated in a chair; at the command "ready now" they had to stand up, walk to a mark located 3 meters away, turn around, walk to the chair, and sit down again. Three attempts were recorded, and the shortest time was considered (Podsiadlo & Richardson, 1991).

Modified Harris Hip Score. During the initial and final assessment of the kinetic rehabilitation program, the patient read and filled out the modified Harris hip score in the company of a qualified professional for its correct completion. The modified Harris hip score assesses the outcome after a hip surgical procedure, considering pain and joint function. The activities considered for assessing functionality are gait (limp, support, distance walked), climbing stairs, putting on socks and shoes, sitting, and using public transportation. The maximum score is 100 points. Between 90 and 100 points is an excellent result, 80 to 89 is good, 70 to 79 is acceptable, and less than 70 is poor (Lara-Taranchenko *et al*., 2022).

Statistical analysis. The GraphPad Prism statistics software (version 8.0®, San Diego, USA) was used. The descriptive management of the variables was by mean ± standard deviation. As appropriate, the Shapiro-Wilk or Kolmogorov-Smirnov test was used to determine the data distribution. Student's t-test or Mann-Whitney test for independent samples was used to observe differences in the behavior of variables between sexes. To determine differences in the behavior of pre- and post-treatment variables, Student's t-

test or Wilcoxon test for paired samples was used. A logistic regression analysis was performed to define the relationship between the event of interest, recovery time < 50 days (25th percentile), and the following variables: obesity (BMI ≥ 30 kg/m^2), operated hip (right), MIS extension ≥ 49 kg (75th percentile), TUG ≤ 11 s (25th percentile) and Harris ≥ 58 points (75th percentile). The Hosmer-Lemeshow test was applied to verify the accuracy of the fit of the model. The modified Harris hip score and multivariate linear regression were used to evaluate the effect of pre-treatment muscle strength on functional recovery after kinetic treatment. The Harris hip score after the 12-week treatment was used as the dependent variable, and measurements of MIS (kg), initial Harris hip score, age, weight, and sex were used as independent variables. The level of statistical significance was set at $p < 0.05$. In addition, the effect size was estimated using Cohen's d and represented as d. An effect size < 0.2 indicates no effect, 0.2 - 0.49 indicates a small effect, 0.5 - 0.79 indicates a medium effect, and ≥ 0.8 indicates a large effect.

RESULTS

Of the total sample (n = 121), 42 cases were excluded because they did not meet the inclusion criteria. Of the 79 participants, 25 (32 %) were men and 54 (68 %) were women. The mean age was 66.15 ± 9.52 years; there were no differences between sexes (p = 0.767). In BMI, there were no differences between sexes (p < 0.768). The initial operated and non-operated MIS was significantly higher in men than in women (p < 0.0001; p < 0.0001, respectively). In the initial TUG, the execution time was significantly shorter in men (p = 0.002). In the Harris hip score, there were no differences associated with sex (p=0.695). Treatment time was significantly lower in men than women (p = 0.002) (Table I).

There was a significant increase in the MIS of the post-treatment operated knee extension in both men and women (p < 0.0001 SE = 0.43; p < 0.0001 SE = 1.22, respectively) (Table II, Figure 1). In the TUG, the execution time was significantly lower post-treatment in both men and women (p < 0.0001 SE = 0.77; p < 0.0001 SE = 0.94, respectively). The final Harris score increased significantly post-treatment in men and women (p < 0.0001 SE = 2.90; p < 0.0001 SE = 1.96, respectively), a fact that occurred equally in all subcategories (Table II, Figure 2).

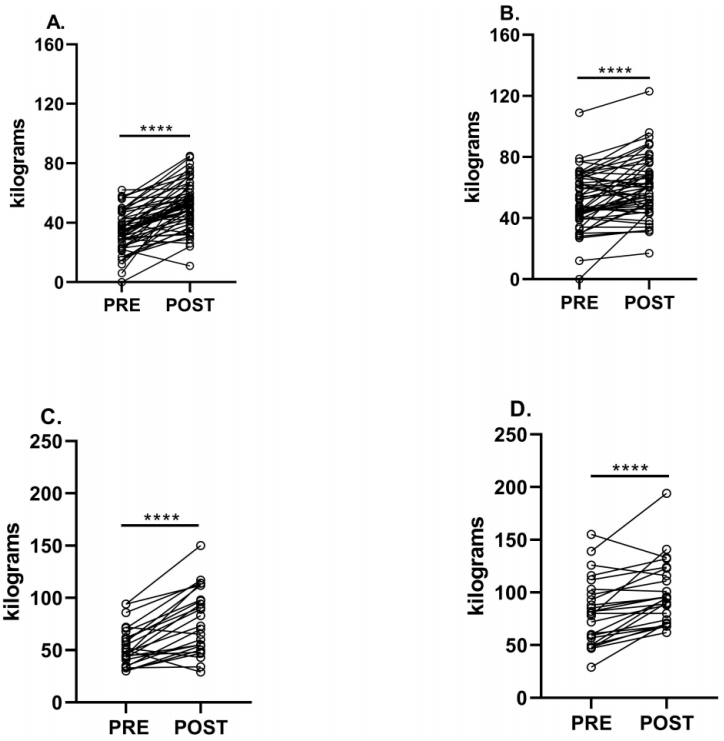

Fig. 1. A. MIS in operated hip female; B. MIS in contralateral hip female; C. MIS in operated hip male; D. MIS in contralateral hip male.

Table I. Baseline anthropometric and functional characteristics of the total sample and divided by sex.

	Total sample	95 % CI	Men	95 % CI	Women	95 % CI	p-value
Sex (%)	79/100		25/32		54/68		
Age (years)	66.15±9.52	64.02-68.29	67.12±8.14	63.76-70.48	65.70±10.14	62.94-68.47	0.767^{MW}
Weight (kg)	74.38±15.74	70.85±77.90	81.48±16.27	74.76-88.20	71.09±14.49	67.14-75.05	0.004^{MW}
Size (m)	1.57±0.08	1.56-1.59	1.64±0.07	1.61-1.67	1.54-0.06	1.53-1.56	< 0.0001^{MW}
BMI (kg/m^2)	29.69±5.15	28.54-30.85	29.95±5.36	27.73-32.16	29.57±5.09	28.18-30.97	0.768^{t}
MIS operated Ext (kg)	40.06±17.79	36.08-44.05	53.04±19.04	45.18-60.90	34.06±13.61	30.34-37.77	< 0.0001^{t}
MIS contralateral Ext (kg)	60.44±27.09	54.38-66.51	80.68±31.06	67.61-93.75	51.07±18.54	46.01-56.13	< 0.0001^{t}
Up and go (s)	18.27±12.06	15.57-20.98	13.83±7.49	10.73-16.92	20.33±13.23	16.72-23.94	0.004MW
Harris (points)	50.39±10.93	47.94-52.84	50.36±9.29	46.52-54.20	50.41±11.69	47.22-53.60	0.695^{MW}
Waiting (days)	38.08±18.39	33.96-42.20	39.88±13.01	34.51-45.25	37.24±20.47	31.65-42.83	0.312^{MW}
Treatment (days)	78.41±49.39	69.36-87.45	57.72±23.48	48.03-67.41	87.98±42.08	76.22-99.74	0.004MW

rpm: repetitions per minute; MIS: maximum isometric strength; MW: Mann-Whitney; t: Student's t-test.

Table II. Anthropometric characteristics, morbimortality, and medical treatment of the total sample and divided by sex.

	Men				Women				
	PRE	POST	CI (95 %)	SE	p-value	PRE	POST	CI (95 %)	SE	p-value
MIS Op Extension (kg)	53.04±19.04	78.16±31.20	65.28-91.04	0.43	0.0001	34.06±13.61	52.54±16.16	48.13-56.95	1.22	< 0.0001[t]
MIS Contralateral Extension (kg)	80.68±31.06	99.16±30.22	86.69-111.6	0.61	0.0001[t]	51.07±18.54	60.13±19.54	54.80-65.46	0.47	< 0.0001[t]
Up and go (s)	13.83±7.49	8.72±2.61	7.642-9.797	0.77	<0.0001[w]	20.33±13.23	8.98±2.98	8,16-9.79	0.94	< 0.0001[w]
Harris (points) Pain	33.60±8.60	38.60±2.29	37.65-39.65	0.64	0.0008[w]	35.00±6.79	37.50±4.20	36.35-38.65	0.42	0.012[w]
Distance walked	6.84±5.42	13.88±2.35	12.91-14.85	1.49	<0,0001[w]	5.25±3.89	12,52±3.32	11.61-13.43	1.85	< 0.0001[w]
Support	2.24±1.26	4.40±0.70	4.10-4.69	2.19	<0.0001[w]	1.81±0.93	4.44±0.63	4.27-4.61	2.66	< 0.0001[w]
Muscle mobility and power	3.40±1.38	4.76±0.66	4.48-5.03	0.83	0.0005[w]	3.33±1.21	4.55±0.83	4.32-4.78	0.62	< 0.0001[w]
Foot care	2.52±1.58	4.52±0.87	4.16-4.88	1.45	<0.0001[w]	2.14±1.71	3.96±1.00	3.68.4.23	1.22	< 0.0001[w]
Limp	2.08±1.68	3.48±0.87	3.12-3.84	0.63	0.0005[w]	1.57±1.56	3.61±1.03	3.31-3.30	1.47	< 0.0001[w]
Stairs	1.64±1.80	4.20±1.00	3.78-4.61	1.63	<0.0001[w]	1.03±1.50	4.03±0.84	3.80-4.26	2.28	< 0.0001[w]
Total	50.36±9.29	73.84±5.52	71.56-76.12	2.90	<0.0001[w]	50.41±11.69	70.63±7.70	68.53-72.73	1.96	< 0.0001[w]

MIS: maximum isometric strength; PRE: pre-treatment; POST: post-treatment; W: Mann-Whitney; t: Student's t-test.

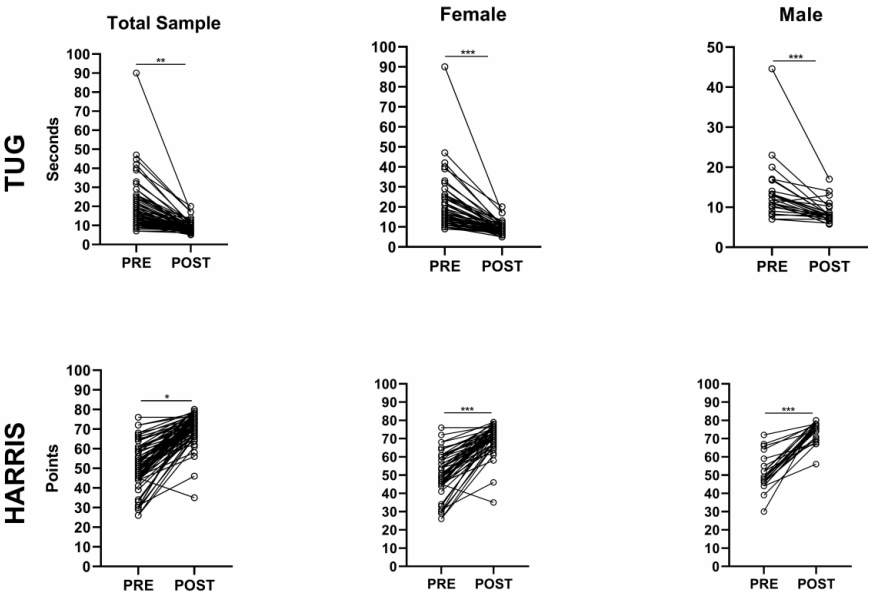

Fig. 2. Results of the TUG and the Harris scale pre and post THC in the total sample and by sex.

In the associations, it was observed that obese patients are 0.79 (79 %) less likely [OR = 0.210; CI (0.057 - 0.777); p < 0.019] to recover in less than 50 days. Patients with right hip surgery are 3.7 times more likely to recover in less than 50 days. In addition, patients with a TUG time of less than 11 seconds are 8.1 times more likely to recover in 50 days or less. Finally, patients with a Harris score higher than 58 points are 3.4 times more likely to recover in less than 50 days (OR = 3.421; CI [0.992 - 1.042]) (Table III).

Table III. Logistic regression of the association between recovery time and obesity, operated hip, MIS in extension, TUG, and Harris, adjusted for sex and age.

	OR [95 %CI]	p-value
Obesity	0.210 [0.057-0.777]	0.019
Sex (Male)	0.231 [0.071-0.753]	0.015
Age (years)	0.960 [0.905-1.018]	0.169
Hosmer-Lemeshow (HL)	0.419	
Hip	3.660 [0.971-13.805]	0.05
Sex (Male)	0.222 [0.069-0.712]	0.011
Age (years)	0.960 [0.903-1.020]	0.183
Hosmer-Lemeshow (HL)	0.238	
MIS Extension	0.871 [0.915-1.025]	0.831
Sex (Male)	0.272 [0.089-0.834]	0.023
Age (years)	0.969 [0.247-3.073]	0.267
Hosmer-Lemeshow (HL)	0.507	
TUG	8.093 [2.314-28.304]	0.001
Sex (Male)	0.448 [0.132-1.520]	0.198
Age (years)	0.997 [0.936-1.063]	0.934
Hosmer-Lemeshow (HL)	0.131	
Harris	3.421 [0.992-1.042]	0.050
Sex (Male)	0.228 [0.069-0.754]	0.015
Age (years)	0.983 [0.927-1.042]	0.554
Hosmer-Lemeshow (HL)	0.423	

OR: odds ratio; CI, confidence interval. Dichotomization of recovery days <50 days; WOMAC <31 points; MIS flexion >32 kg, MIS extension >35 kg.

Table IV lists the results of the linear regression analysis to assess the effect of pre-kinetic treatment MIS on function at 12 weeks of treatment. Regarding the association between MIS and the Harris score, it was noted that, for a 1 kg increase in this measure compared to the initial assessment, the Harris score, after 12 weeks of treatment, increased by 0.179 points ($\beta = 0.179$; $p = 0.050$).

Table IV. Effect of quadricep muscle strength on functionality. Hip arthroplasty outcomes: results of linear regression analysis.

	R^2	β±SE	p-value
Knee extension pre	22.0 %	0.179±0.05	0.050
Knee extension post	15.7 %	0.014±0.03	0.707

The analysis was corrected for age, weight, height, and initial Harris score. The coefficients represent the difference in Harris scores per unit increase in the independent variable. The coefficient b= 0.179 for the knee Extensor MIS indicates that, for the 1 kg increase in this measurement at baseline assessment, the Harris score following 12 weeks of treatment is 0.179 points higher.

DISCUSSION

This study aimed to compare quadricep strength pre- and post-kinetic treatment and to determine its impact on functional recovery in patients with THA with a lateral approach. In this regard, the main results indicate a significant increase in the quadricep MIS in both lower limbs, a significant decrease in TUG time, and a significant increase in the total Harris score. Finally, being normal weight, having undergone surgery on the right hip, and having a Harris score higher than 58 points are associated with a greater chance of recovery in less than 50 days.

People with knee and hip osteoarthritis are more likely to have muscle weakness and lower functionality compared to the general adult population.11 Those with greater muscle mass in the lower limbs achieve greater functionality in ADL (Gormaz-Veloso *et al.*, 2022). Specifically, our results indicate that the final MIS is greater than the initial one, both in the operated hip and the non-operated hip, mainly due to the guided and dosed training through physiotherapy sessions. When analyzing the MIS in knee extension of the operated and non-operated extremity of both sexes, it is observed that men presented greater muscle strength at the initial and final stages of the treatment, in addition to the initial MIS results in men being similar to the final results of the post-treatment MIS in women. Physiological variables could explain that difference, be it hormone levels or muscle mass volume (Jacob *et al.*, 2022; Gormaz-Veloso *et al.*, 2022).

On the other hand, TUG execution time decreased significantly in men (13.83 ± 7.49 - 8.72 ± 2.61; $p < 0.0001$) and women (20.33 ± 13.23 - 8.98 ± 2.98; $p < 0.0001$). Although there is a difference between sexes at baseline, the final time results are similar post-treatment. The significance of these results lies in two points: i) TUG times ≤ 11 seconds have odds of 8.093 (95% CI 2.314 - 28.304; $p = 0.001$) of recovering in less than 50 days (Table III), and ii) TUG times ≤ 13.5 seconds are related to low risk of falling in the older adult (Barry *et al.*, 2014).

In terms of functionality, the results from Holstege *et al.* (2011) indicate that greater preoperative strength of the extensors of the operated knee is associated with improved function as measured by the WOMAC scale at 12 weeks postoperatively after THA. This coincides with the results of the present study, where there is an increase of 0.179 points in the Harris score for each kilogram of strength gained after the treatment. This confirms that quadricep muscle strength before or after surgery is related to functionality. This is important, considering that total Harris scores ≥58 points are 3.421 (95% CI 0.992 - 1.042; $p < 0.050$) times more likely to recover in less than 50 days (Table III). In this context, muscle strength training should be an important point in the rehabilitation process for THA due to its impact on structure and functionality (Matheis & Stöggl, 2018).

Among the limitations of this study is that an objective measurement of abductor muscle strength and its relationship to knee extensor muscle strength pre- and post-treatment was not performed. In addition, it could be complemented by future studies with patient follow-up for a year after discharge. These two pieces of information would provide a complete picture of its evolution and whether the effects of the treatment are maintained or improved over time. The conclusions these studies indicate an increase in knee extension MIS of the operated hip after treatment in both sexes. At the same time, functionality increased post-treatment in both men and women. In addition, there are conditioning factors such as weight, sex, and the side of the operated hip that have an impact on recovery times. Therefore, it is suggested that these variables be considered in recovery time planning.

Clinical Messages

- Post-THA rehabilitation highlights the importance of strengthening the quadriceps, improving muscle strength and functionality.
- The personalized approach to therapeutic exercise contributes to the global advancement of physical medicine and rehabilitation, optimizing patient outcomes and quality of life.

Declaration of conflicting interests. The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

GORMAZ-VELOSO, A.; ÁLVAREZ, R.; MUÑOZ-COFRÉ, R.; VALENZUELA-AEDO, F.; DEL SOL, M. & CANTILLANA, L. W. Impacto de la rehabilitación con kinesioterapia en la fuerza y funcionalidad del músculo cuádriceps femoral en pacientes con artroplastía total de cadera. *Int. J. Morphol., 42(4)*:1033-1038, 2024.

RESUMEN: El objetivo del estudio fue medir la fuerza del músculo cuádriceps femoral después de la artroplastia total de cadera (THA, por sus siglas en inglés) y el tratamiento kinésico, para determinar su impacto en la recuperación funcional de pacientes con osteoartritis de cadera. En el estudio participaron 79 pacientes con THA (25 hombres y 54 mujeres). Se excluyeron quienes tuvieron tratamiento Kinésico previo fuera del hospital, operación por fractura de cadera y no completar el tratamiento. Las principales medidas tomadas fueron: Fuerza Máxima Isométrica (MIS), Time UP and GO (TUG), Puntuación Modificada de Harris de Cadera. Hubo un aumento significativo en la MIS de la extensión de rodilla del lado operado después del tratamiento tanto en hombres ($p<0,0001$, EE=0,43) como en mujeres ($p<0,0001$, EE=1,22). En el TUG, el tiempo de ejecución fue significativamente menor después del tratamiento en hombres ($p<0,0001$, EE=0,77) y mujeres ($p<0,0001$, EE=0,94). La puntuación final de Harris aumentó significativamente después del tratamiento en hombres ($p<0,0001$, EE=2,90) y mujeres ($p<0,0001$, EE=1,96). En cuanto a la asociación entre MIS y la puntuación de Harris, se observó que por cada aumento de 1 kg en esta medida en comparación con la evaluación inicial, la puntuación de Harris aumentó en 0,179 puntos después de 12 semanas de tratamiento ($\beta=0,179$; $p=0,050$). En conclusión se observó un aumento en la MIS de la extensión de rodilla del lado operado después del tratamiento en ambos sexos. Al mismo tiempo, la funcionalidad aumentó después del tratamiento tanto en hombres como en mujeres.

PALABRAS CLAVE: Artroplastía total de cadera; Tratamiento kinésico; Funtionalidad; Músculo cuadríceps femoral.

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