Volume 92, No. 2 February 2011

Archives of Physical Medicine and Rehabilitation

In This Issue:

Official Journal of the
AMERICAN CONGRESS OF REHABILITATION MEDICINE

ELSEVIER

ORIGINAL ARTICLE

Preoperative Quadriceps Strength as a Predictor for Short-Term Functional Outcome After Total Hip Replacement

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ABSTRACT. Holstege MS, Lindeboom R, Lucas C. Preoperative quadriceps strength as a predictor for short-term functional outcome after total hip replacement. Arch Phys Med Rehabil 2011;92:236-41.

Objective: To determine the preoperative strength of the muscle group of the lower extremity that is most important in predicting functional recovery after primary unilateral total hip replacement (THR).

Design: Prospective observational study with inception cohort.

Settings: Joint care program (hospital care/clinical division of a nursing home/outpatient physical therapy).

Participants: Patients (N=55) undergoing primary unilateral THR.

Interventions: Not applicable.

Main Outcome Measures: Baseline measures within 2 weeks preoperative and follow-up at 6 and 12 weeks postoperative included isometric strength measurement of the hip (flexors, extensors, abductors, adductors) and knee (flexors, extensors) musculature using a handheld dynamometer. Functional outcome was tested using performance-based (Timed Up and Go Test, 6-Minute Walk Test) and self-report measures (Western Ontario and McMaster Universities Osteoarthritis Index, subscale Physical Function [WOMAC PF], 36-Item Short Form Health Survey subscale Mental Health, visual analog scale for pain).

Results: Of the patients (N=55; mean age, 72.7±6.8y; 41 women) included; 18 dropped out, leaving 37 patients for analyses. After correction for WOMAC PF score at baseline, body mass index, sex, and age, the preoperative knee extensors strength measure of the operated site was the only muscle group showing a significant effect on functional outcome measured by using the WOMAC PF at 12 weeks postoperatively (R^2=.355; β=−.105; P for β=.004).

Conclusion: Preoperative greater knee extensor strength of the operated site is associated with better physical function, measured by using the WOMAC PF at 12 weeks postoperative.

Key Words: Arthroplasty; Hip; Muscle strength; Quadriceps muscle; Rehabilitation; Replacement.

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No commercial party having a direct financial interest in the results of the research supporting this article has or will confer a benefit on the authors or on any organization with which the authors are associated.

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0003-9993/11/9202-00337$36.00/0
doi:10.1016/j.apmr.2010.10.015

OSTEOARTHRITIS IS THE MOST common chronic musculoskeletal disorder worldwide. The most important consequences of osteoarthritis in the hip are pain; morning rigor; crepitus; decreased mobility, muscle strength, and stability; deformation of the joint; and decreased aerobic capacity. The prevalence of people with osteoarthritis is increasing yearly because of the increased life span and bulging cohort of baby boomers.[1] The prognosis for demographic trends in The Netherlands shows an increase of 52% between 2007 and 2040 for the absolute number of patients with osteoarthritis.[2] Total joint replacement is an effective intervention used in patients with severe osteoarthritis, with 202,500 THRs performed in the United States in 2003 and an expected 174% growth to 572,500 in 2030.[3] In The Netherlands, 19,546 THRs were undertaken (68% women) in 2007 because of osteoarthritis.

Preoperative prognostic determinants of functional recovery are important for patients, physicians, and therapists. Several studies focused on preoperative predictors of postoperative functioning after hip replacement. Factors associated with functional recovery included age, sex, level of pain, number of comorbid conditions, site of arthroplasty, BMI, SF-36 score, WOMAC score, short-term self-efficacy, and patient perceptions concerning the outcome.[4-10]

Muscle atrophy in patients with osteoarthritis due to chronic inactivity was another factor affecting postoperative functional recovery after THR, and strength deficits can persist after hip replacement.[11-13] Another study[14] found a significant relation between quadriceps strength and functional recovery with TKR, but at present, it is still unclear which muscle group is most important in predicting functional recovery after THR.

The aim of the study was to investigate the muscle group of the lower extremity measured preoperatively that is associated most with short-term functional recovery in patients undergoing primary unilateral THR. We hypothesized that specific muscle groups measured preoperatively can predict short-term functional recovery in patients undergoing primary unilateral THR.

List of Abbreviations

6MWT	six-minute walk test
ADL	activity of daily living
BMI	body mass index
HHD	handheld dynamometer
SF-36 MH	Medical Outcomes Study 36-Item Short-Form Health Survey, subscale Mental Health
THR	total hip replacement
TKR	total knee replacement
TUG	Timed Up & Go
VAS	visual analog scale
WOMAC PF	Western Ontario and McMaster Universities Osteoarthritis Index, subscale Physical Function

METHODS

Design

We performed a prospective observational study with a preoperative inception cohort. The primary endpoint was physical functioning at 12 weeks postoperatively. Outcome measurements were performed within 2 weeks preoperatively and at 6 and 12 weeks after surgery, when study participants visited an outpatient clinic. All measurements were performed by the same physical therapist (M.S.H.). Four subjects were measured by a different physical therapist because they were treated at another location. Both assessors were trained physical therapists.

Participants

The study sample consisted of elderly patients scheduled to undergo primary unilateral THR for advanced osteoarthritis in the Zaans Medical Centre, The Netherlands. Hip arthroplasty consisted of a cementless acetabular component and hip stem component. Patients participated in the joint care program, where they were provided with oral and written information about the enrollment procedure, surgical procedures, and postoperative therapy during a preoperative information meeting. The first day after surgery, all patients were allowed to use walking aids while 100% weight-bearing capacity of the prosthesis was assumed. On average, patients remained on the surgical ward for 4 days and received clinical rehabilitation treatment for 8 to 12 days thereafter. After discharge, patients were referred to 1 of the 4 outpatient physical therapy settings that cooperated with the joint care program and had additional rehabilitation treatment for approximately 60 minutes twice a week. No preoperative physical therapy was prescribed. The clinical rehabilitation and outpatient physical therapy programs were in line with the orthopedic guidelines from the Dutch institute for health care improvement.

Patients were eligible for inclusion if they provided informed consent to participate in the study and the joint care program (clinical and postclinical pathway) and had the ability to answer questions in Dutch or English. Exclusion criteria were patients scheduled for revision arthroplasty, Birmingham Hip Replacement, or bilateral arthroplasty (contralateral THR <1y before). Patients with significant neuromuscular disease, extreme deformation of extremities, and mental disorders also were excluded. Eligible patients were asked for informed consent by 1 of the 3 orthopedic surgeons involved in the surgical procedure or by their surgeon assistant.

Measures

Because functional recovery after THR is multifactorial, we used performance-based and self-report measures for this study.

Strength measurement. The MICROFET2[a] was used as an HHD to assess isometric strength of the flexors, extensors, adductors, and abductors of the hip and flexors and extensors of the knee (fig 1). An HHD is a widely used, reliable, and valid instrument to measure isometric peak force, also in elderly patients,[15-17] and interobserver reliability appeared to be high (intraclass correlation coefficient=.94) in a study with subjects after THR and TKR.[18]

Tests were performed in a gravity-neutralized position with the patient lying supine, except for knee flexion and extension, which were tested with the subject in an upright sitting position. Tests were carried out according to a standardized protocol,[15] except for measurements of the hip extensors and adductors, which were not recorded. We also performed these

Fig 1. The HHD.

measurements in a gravity-neutralized position. Measurements were performed 3 times successively, and the highest score was used for analysis.

Performance-based measures. Basic functional mobility was measured by using the TUG test and 6MWT. Both are validated to measure functional ability in elderly patients.[19,20] Patients were permitted to use the regular walking aids used at the given stage of recovery. For the 6MWT, standard phrases of encouragement were allowed.

Performance-based measures deal with functional performance in a clinical setting, whereas functional outcome measures deal with the result of true ADL performance. Instead of a real ADL measurement, the latter also might be established by means of a self-report questionnaire.

Self-report measures. Functional recovery, the outcome of interest, was measured by using the WOMAC PF (Dutch version).[21] The WOMAC PF (17 items) is a self-assessed disease-specific measure for patients with osteoarthritis of the knee and hip. Responses were given by means of an ordinal 5-point rating scale, with 0 indicating no problem and 4 indicating an extreme problem with the activity. Scores for the PF subscale range from 0 to 68 points. To assess MH, we used the SF-36 MH subscale (Dutch version).[22] The subscale includes 5 items: depression, anxiety, behavioral control, emotional control, and general positive affect. Scores range from 0 to 70, with higher scores indicating lower levels of mental health. To assess subjective pain, we used a VAS with the following question[23]: "Which level of pain do you subscribe to your affected hip?," with 0 indicating no pain and 10 indicating worst pain.

Statistical Analysis

Post hoc sample-size calculations indicated that with our expected inclusion of 40 patients (excluding attrition), the multiple linear regression test of R^2 of 0 for 5 covariates would have 80% power to detect an R^2 of .30. We aimed to include 50 patients because we expected a 20% attrition rate. Eventually, we included 55 patients, of whom 37 could be analyzed (discussed next).

To assess the effect of preoperative muscle strength on functional recovery at 12 weeks postoperatively measured by using the WOMAC PF, we used multivariable linear regression analysis. WOMAC PF score at 12 weeks after surgery was used as the dependent variable, and the selected muscle

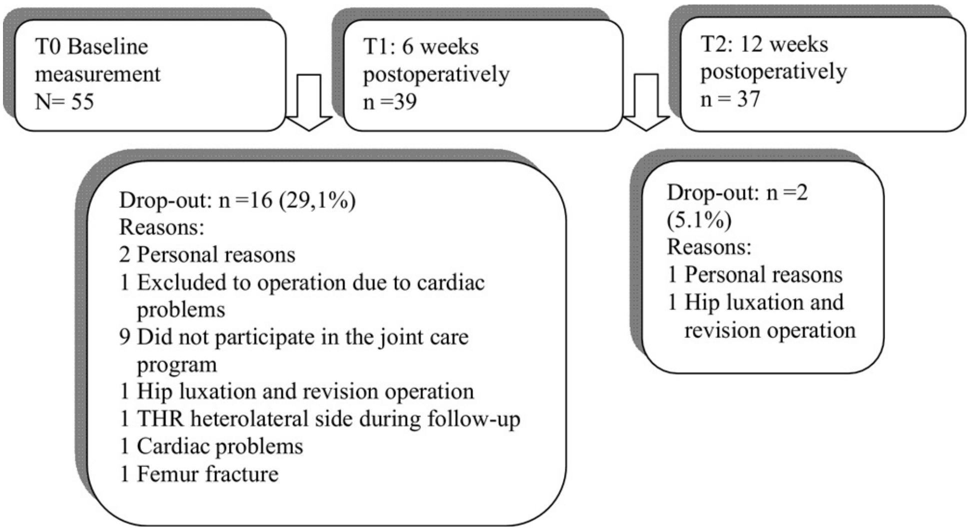

Fig 2. Inclusion flow chart.

strength measures (newtons), as predictors while correcting for baseline WOMAC PF score, age, BMI, and sex. A predictor variable was considered statistically significant at P less than .05 in the multivariable model. Multicollinearity was deemed concerning if the variance inflation factor for any independent variable was greater than 5. Graphical examination of standardized residuals against total muscle strength measurements and scatter plots of dependent and independent variables were used to examine violation of the linearity assumption in all regression models.

RESULTS

Descriptive Data

Patients were included between 2008 and 2009. Of 55 eligible patients, 18 dropped out of the study for various reasons, leaving 37 patients for analysis, which is in accordance with our sample size (fig 2). Patient demographic characteristics at baseline are listed in table 1. Baseline characteristics of patients who dropped out were not relevantly different from those with complete follow-up. At 12 weeks, there was 1 missing value for the 6MWT, VAS, and TUG test. We used values from the 6-week assessments in case of missing values at 12 weeks (last observation carried forward). The WOMAC PF had 21 missing responses for item 13 (level of difficulty going in and out of bath) at the 3 measurement points because subjects used a shower. We replaced the missing values for the WOMAC PF bath item with the subject's mean item score. There were 12 patients with 5 or fewer missing items on the WOMAC PF. For these patients, we replaced the missing value with the highest score of 4 (extreme difficulty) because we assumed that patients skipped the activity because they were unable to perform it.

Descriptive statistics (mean ± SD or median with interquartile range) for measures preoperativelyly and at 6 and 12 weeks postoperative are listed in table 2. At 6 weeks postoperatively, all outcomes had improved significantly compared with the preoperative state, except for knee extensors, TUG test, and 6MWT. All outcomes had improved significantly at 12 weeks postoperatively compared with the (preoperative) baseline score. At baseline, all muscle strength measures from the operated side were significantly lower in comparison to the nonoperated side. At 6 weeks' follow-up, hip extensors, hip abductors, knee flexors, and knee extensors still showed significantly lower strength compared with the nonoperated side. At 12 weeks' follow-up, only hip abductor and knee flexor strength of the operated side were still significantly lower. WOMAC PF score had improved significantly at 6 and 12 weeks postoperatively compared with baseline.

Table 3 lists results of linear regression analysis to assess the effect of preoperative muscle strength on functional outcome (WOMAC PF score at 12 weeks postoperatively) after THR. After correction for WOMAC PF score at baseline, BMI, sex, and age, knee extensor strength (quadriceps muscle) of the operated site was the only variable showing a significant effect on functional outcome (WOMAC PF score) at 12 weeks postoperatively. β coefficient was $-.105$ (P=.004), indicating that a difference in knee extensor strength at baseline of 20N is associated with

Table 1: Baseline Characteristics of Included Patients

Characteristic	Total Sample (N=55)	Complete Follow-up (n=37)	Drop-out 12 wk (n=18)
Mean age (y)	72.7±6.8	72.1±6.4	73.9±7.5
Women	41 (74.5)	28 (75.7)	13 (72)
THR left side	28 (50.9)	18 (48.6)	10 (55.6)
Operated hip, dominant side	30 (54.5)	22 (59.5)	8 (44.4)
Approach posterior	38 (69.1)	27 (73)	11 (61.1)
Mean BMI (kg/m^2)	28.0±4.1	27.8±3.9	28.5±4.2
Comorbid condition	34 (62)	22 (60)	12 (68)

NOTE. Values expressed as mean ± SD or n (%).

Table 2: Descriptive Statistics for Muscle Strength, WOMAC PF, SF-36-MH, VAS, TUG, and 6MWT Measured Preoperatively and at 6 and 12 Weeks Postoperatively

Outcome	Preoperative (N=55)	6 wk (n=39)	12 wk (n=37)
Hip			
Flexors			
Operated side	114.3±39.1*	136.5±43.9	162.5±44.51
Nonoperated side	130.7±42.6	147.7±43.3	171.6±5.0
Extensors			
Operated side	162.1±51.9*	190.9±49.7*	228.1±55.7
Nonoperated side	187.1±52.4	217.2±54.8	235.2±51.2
Abductors			
Operated side	129.9±54.1*	150.5±57.1*	192.8±59.5*
Nonoperated side	170.2±59.0	187.0±65.4	207.8±69.3
Adductors			
Operated side	106.4±38.1*	129.5±37.1	152.9±51.31
Nonoperated side	126.8±40.8	138.8±52.8	160.6±57.6
Knee			
Flexors			
Operated side	139.4±46.8*	155.3±38.1*	174.0±48.8*
Nonoperated side	152.0±51.7	170.2±44.2	185.0±53.0
Extensors			
Operated side	192.7±74.2*	190.8±60.4*†	233.2±74.62
Nonoperated side	222.2±69.9	222.6±67.2†	246.7±66.7
WOMAC PF (0−68)	34.7±13.8	21.6±13.3	14.7±9.6
SF-36 MH (0−70)	50.5±6.7	55.6±8.5	57.8±10.6
Median VAS pain (IQR)	4.7 (3.1−6.0)	0.3 (0−1.5)	0 (0−0.3)
TUG test (s)	13.5±6.0	12.9±4.9†	10.6±4.3
6MWT (m)	317.9±112.3	313.8±89.6†	380.4±99.0

NOTE. Values expressed as mean ± SD unless indicated otherwise. Muscle strength in Newtons. All comparisons between strength measurements preoperatively and 6 weeks and 12 weeks postoperatively were significant at $P<.05$ unless indicated otherwise.
Abbreviation: IQR, interquartile range.
*Strength measures from the operated side were significantly ($P<.05$) lower than the nonoperated side (2-sample *t* test).
†Not significant (paired *t* test).

a 2-point (20×.105) lower WOMAC PF score at 12 weeks, to be interpreted as a better functional outcome. Excluding the 3 patients who used a walking aid (elbow cane) at follow-up did not alter results: β equals −.119 (P=.006). Also, we reanalyzed data for posterior (n=27) and lateral (n=10) surgical approaches separately. Results were similar to those for the groups combined. For the posterior surgical approach, β equals −.099, and for the lateral approach, β equals −.147. Result of the the test for interaction of knee extensor strength at baseline and surgical approach were not significant (P=.51), indicating that surgical approach did not influence results.

We repeated the analysis using TUG test, 6MWT, SF-36 MH, and VAS scores as dependent variables indicating functional outcome, but none was significantly related to preoperative muscle strength.

Table 3: Effect of Preoperative Muscle Strength on Functional Outcome After THR: Results of Linear Regression Analysis

	R^2	β±SE*	P for β
Hip flexors	22.0%	−0.086±0.053	0.116
Hip extensors	16.7%	−0.022±0.032	0.496
Hip abductors	24.1%	−0.078±0.041	0.069
Hip adductors	17.5%	−0.055±0.062	0.380
Knee flexors	23.8%	−0.091±0.049	0.074
Knee extensors	35.5%	−0.105±0.034	0.004

NOTE. No violation of assumptions of regression models were observed. Variance inflation factors were less than 2, and residuals had a symmetrical distribution.
*Corrected for age, sex, baseline WOMAC PF score, and BMI. β coefficients represent the difference in WOMAC PF scores per unit increase in the independent variable. For example, β= −.105 for Knee extensors indicates that per 1-N higher knee extensor measure preoperatively, 12-week WOMAC PF score is .105 point lower. Thus, a patient with 20-N higher preoperative strength has on average a 20×.105=2 points lower (better) WOMAC PF score 12 weeks postoperatively.

DISCUSSION

The primary aim of this study was to investigate which muscle group of the lower extremity in the preoperative phase is most important in predicting short-term functional recovery after THR, measured by using the WOMAC PF. Our analysis showed the knee extensors (quadriceps muscle) of the operated site as the only significant predictor for 12-week postoperative physical function measured by using the WOMAC PF. The relation between preoperative quadriceps function and postoperative recovery also was reported in studies with patients undergoing TKR.[14,24] To our knowledge, this is the first study that focused on this relationship with THR patients. One study[25] described the relationship of strength as a preoperative predictor in THR, suggesting that preoperative Modified Barthel Index score and isokinetic peak strength of hip flexors and extensors were strong predictors of timing for hospital discharge. As described in the introduction, several studies focused on the relationship of preoperative variables to postoperative function after hip and knee arthroplasty. Our study also confirms the "better in, better out" principle: better preoperative function leads to better postoperativefunction.

A systematic review[26] suggested that physical therapy in people with hip osteoarthritis may be beneficial, but results have not been established. Suetta et al[27] described an early postoperative protocol of unilateral resistance training of the quadriceps that improved both impairment and function and shortened hospital length of stay after THR. The investigators suggested that further research is necessary to study the effect of a preoperative quadriceps strengthening program on postoperative functional rehabilitation.

At the 6-week postoperative measurement, knee extensors, TUG score, and 6MWT score showed no significant improvement. Mizner et al[24] reported that preoperative quadriceps strength was associated significantly with physical performance of the TUG test and 6MWT in a sample of TKR patients. In contrast to the findings of outcome performance in TKR reported by Mizner,[24] we could not detect a significant outcome performance based on quadriceps strength in THR. However, in our study, preoperative quadriceps strength correlated significantly with self reported outcome on the WOMAC PF. A possible explanation could be that this self-report measurement scale may be influenced by patients' overestimation and socially desirable answers. Second, the study of Mizner[24] showed that quadriceps strength appeared to be a significant predictor in performance-based outcome in TKR, whereas this could not be confirmed in our study of THR. This could be explained because the quadriceps muscle group is a primary mover in knee extension, whereas hip flexion using the quadriceps muscle group is of minor importance. In conclusion, extension of the knee joint in TKR is of major importance with respect to performance outcome, whereas flexion of the hip joint in THR by the same muscle group (mm. quadriceps) contributes only a very limited extent to performance outcome.

Hip abductors and knee flexors at 12 weeks were the only muscle groups that had significantly lower muscle strength compared with nonoperated hip strength at the 12-week follow-up, but both significantly improved in comparison to baseline data. Whether this should have implications in the rehabilitation regimen in terms of selective muscle strength training is disputable. In our study, we did not detect any muscle group to be a significant predictor of functional outcome.

In addition, persisting muscle fiber atrophy after THR is described as an important factor of decreased progress in functional rehabilitation in several studies,[11,13] with the possibility to persist for 2 years after THR. There are different explanations for persisting muscle atrophy and differences in recovery of the independent muscle groups. One is fat infiltration in the hip muscles due to preoperative inactivity as a negative predictor in muscle recovery.[13] Also neuromuscular activation deficits,[12] the trauma of the surgical procedure, and persisting inactivity may influence rehabilitation of hip muscles. Patients with osteoarthritis who had an inactive life style before THR due to pain and loss of mobility frequently persist in such inactivity after THR.[28]

Study Limitations

Our study had several limitations. We had a small sample size, which can affect the external validity of the study. However, results of descriptive statistics showed data similar to other studies, confirming that our sample was generalizable to a group of patients with hip osteoarthritis and THR.[7,13,29] There was a dropout rate of 32.7% of the total sample: 29% left the study before the postoperative measurement at 6 weeks, of which 16.4% decided not to participate in the joint care program, mostly because they had no transportation to 1 of the 4 outpatient facilities of the joint care program. However, we had a low dropout rate (5.1%) at the 12-week follow-up measurement. The last measurement in our study was at 12 weeks postoperatively; thus, no long-term follow-up was measured. In our center, postoperative physical therapy usually ends after 3 months because most patients reach their functional endpoints within that time frame and the additive benefit of rehabilitation therapy flattens out. In addition, in longer follow-up, other external factors irrelevant to the rehabilitation course could distort the association we aimed to examine in these elderly patients. Because of the small sample, we can adjust for only a limited number of confounders. We corrected for the most important ones, which were BMI, baseline score of the dependent variable, age, and sex.

In our study, we had 2 surgical procedures, the lateral and posterior approach (73% of analyzed subjects). In our study, surgical approach also was not associated with WOMAC PF score at follow-up.

Muscle strength measurement using a dynamometer was used widely in other studies. It is an objective measurement of muscle peak force. The limitation of dynamometry occurs when the outcome assessor is unable to stabilize the patient in to the position according to protocol. This can happen occasionally when measuring the quadriceps. If stabilization of the patient appears to be impossible, the muscle cannot be tested isometrically and a concentric test procedure remains. This might underestimate the absolute level of peak force of the mm. quadriceps. Despite these limitations, the HHD is a proven, reliable, and valid instrument measuring strength in the elderly population after THR.[15-18]

CONCLUSIONS

Preoperative greater knee extensor strength of the operated site is associated with better physical function, measured by using the WOMAC-PF at 12 weeks postoperatively. We suggest that studies with larger samples are required to confirm our findings.

Acknowledgments: We thank the orthopedic surgeons (R.J.P. Noorda, MD, K. Styblo, MD, J.P.W. v.d. Aa, MD) and orthopedic assistants of the Zaans Medical Centre for collaboration and all physiotherapists from the joint care program for support.

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Supplier

a. MICROFET2; Biometrics BV, Transistorstraat 46-II, 1322 CG Almere, The Netherlands.