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Hip abductor strength and fatigue are associated with activity levels more than one year after total hip replacement

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Abstract

Despite improvements in pain and function, people who undergo total hip arthroplasty (THR) may not always return to desired levels of physical activity (PA). The factors associated with low activity levels are not fully understood. Abductor weakness and fatigue have both been proposed as factors that limit activity in older adults or people with hip osteoarthritis, but have not been investigated after THR. We hypothesized that abductor weakness and fatigue are associated with lower activity levels in people who have undergone a THR and that fatigue mediates the association between abductor strength and activity. We evaluated 16 subjects (24±10 months post-THR; age 56.8±8.4 yrs; BMI 31±7 kg/m²). Fatigue was assessed using the PROMIS Fatigue Short-form 7a. Peak isometric hip abductor torque was assessed using a dynamometer with subjects in a sidelying position. We assessed activity level using the UCLA activity score. We used Pearson correlations to explore the associations among the variables. Next we used a three-step linear regression procedure to test whether or not fatigue acted as a mediator between abductor torque and UCLA activity scores. Higher abductor torque was associated with less fatigue ($R^2=0.275$; $p=0.037$) and with higher UCLA scores ($R^2=0.488$, $p=0.003$). Higher fatigue was associated with lower UCLA scores ($R^2=0.307$, $p=0.017$), however there was no evidence of mediation. This suggests that addressing both abductor strength and fatigue may increase physical activity.

Statement of Clinical Significance—Fatigue and abductor weakness should be evaluated in sedentary THR patients presenting for long-term follow up.

Keywords

Total Hip Arthroplasty; Physical Activity; Fatigue; Muscle Strength; Dynamometer

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Introduction

For those undergoing total hip replacement (THR) surgery, regaining the ability to participate in everyday and recreational physical activity is among the most commonly stated goals, motivations, or expectations.^{1, 2} Unfortunately, while patients often self-report higher postoperative activity levels on survey instruments,³⁻⁵ several studies have shown that objectively-measured physical activity does not increase substantially after THR.^{4, 6-10} Although patients after THR often overestimate their activity level, approximately 19% and 45% of people after THR, depending on what measurement tool and cutpoints used, engage in low levels of physical activity or are sedentary.^{4, 6, 7, 11, 12} Improving activity levels after THR surgery is important both because of the physical activity is critical for healthy aging,^{13, 14} and in order to fully meet the expectations of THR patients. Barriers to physical activity have been extensively investigated in general populations of older adults and in people with OA, but are not well understood in people with THRs. This study investigates the potential relevance of two published models proposed to explain physical activity limitations in healthy older adults or those with OA: the energy limitation model^{15, 16} and the activity avoidance model.^{17, 18}

The energy limitation model proposes that people with inefficient gait patterns consume excessive energy when performing ordinary activities. Ordinary activities are therefore excessively fatiguing and those affected reduce their activity levels overall to compensate. Several studies have linked increased energy use in older adults with reduced PA.^{15, 16} There is evidence in the OA literature suggesting this model could apply to people with THRs. A study by Holsgaard-Larsen and Roos that compared energy expenditure and step counts for total hip or knee replacement candidates and control subjects, showed that people awaiting joint replacement expended the same amount of energy each day, compared to controls, but walked fewer steps.¹⁹ This suggests that people with endstage OA indeed walk with more energetically costly gait patterns. Many studies have shown that some gait characteristics in endstage hip OA are retained after THR,^{5, 20-23} or that gait patterns are abnormal after THR compared to control subjects.^{20, 22-24} It is possible that walking inefficiencies persist as well. In addition, fatigue is a common OA symptom,^{25, 26} and has been associated with lower physical activity in people with hip or knee OA.^{25, 27} There have been no studies, to our knowledge, that evaluate whether or not THR improves fatigue. Consequently, we do not yet have evidence to rule out the energy limitation model of activity restriction.

The activity avoidance model proposes that people in pain may avoid taxing physical activities. This activity avoidance leads to reduced muscle strength that, in turn, reduces the ability to be physically active, thereby creating a cycle promoting low physical activity levels.^{17, 18} Muscle weakness, particularly weakness of the hip abductors, is commonly seen in people with severe hip OA.²⁸⁻³⁰ Abductor insufficiency may lead some people with hip OA to avoid physical activities that challenge dynamic stability in the frontal plane or that involve single limb balance. Most THR patients achieve good levels of pain relief, however dynamic abductor dysfunction is still common. The activity avoidance model may therefore still be applicable after surgery, however, both in light of studies that show that muscle weakness persists after THR,³¹⁻³⁴ and that preoperative dynamic abductor dysfunction is highly predictive of postoperative abductor impairment.²¹

The purpose of this study was to explore the association of fatigue and abductor strength on self-reported physical activity in people with THRs. We further postulate that the energy limitation model and the activity avoidance model may work together to reduce physical activity after THR (Figure 1). Fatigue may arise because gait compensations, in particular those associated with hip abductor weakness, such as increased trunk excursion, increase the energy cost of walking.³⁵ Accordingly, we tested the hypothesis that both increased fatigue and decreased peak isometric abductor torque (abductor strength) are significantly correlated with reduced activity levels, and further, that fatigue mediates the association between abductor strength and activity level.

Methods

Subjects

This cross-sectional cohort study (level of evidence 3) was approved by the Institutional Review Board of our university. All subjects provided written informed consent. We recruited community dwelling adults through flyers, word of mouth, and social media, and from the practice of an academic orthopedic surgeon over a 7 month period. Eligibility criteria included: (i) THR at least 1 year and no more than 5 years before testing; (ii) the ability to walk unassisted for 10 minutes; (iii) not actively participating in a physical therapy program; and (iv) no other medical conditions that would interfere with safe completion of the protocol (e.g. stroke or recent/actively symptomatic musculoskeletal injury). The rationale for these criteria was that we wanted subjects to reflect a heterogeneous general population of persons living with total hip replacements, who may or may not consider themselves to be “patients”. This strategy necessarily meant that surgical approaches, amount and type of previous rehabilitation, and other aspects of perioperative management were not controlled. 41 people were referred (either through the surgeon or self-referred) and contact was attempted. Of these, we successfully contacted 24 potential subjects for screening (other candidates either had incorrect contact information or did not respond to our messages). Two candidates were deemed ineligible. Two eligible subjects did not attend scheduled sessions and were unable to reschedule. Finally, two enrolled subjects were unable to complete study activities due to equipment issues (e.g. unable to comfortably lay on dynamometer due to body size). The final sample consisted of 5 men and 11 women (Table 1).

Abductor strength assessment

Hip abductor strength was measured as peak isometric torque for the operated-side hip. Subjects were positioned in side-lying position³⁶ on the reclined seat of a dynamometer (Biodex, Shirley, NY, USA). The axis of the dynamometer testing arm was aligned with the subject's greater trochanter. Limb weight was measured at 20 degrees of static abduction with the limb relaxed and fully supported with padding located on the thigh superior to the knee. Isometric torque was then measured as subjects pushed against the padded surface of dynamometer arm. Testers encouraged subjects to give consistent maximal effort but not to the point of pain. After set-up and instructions, subjects performed three 5 second bouts, alternated with 30 seconds of rest. We averaged the peak isometric torque measured from the three bouts and normalized the result to body mass (Nm/kg).

Fatigue assessment

Self-reported fatigue was measured using the Patient-Reported Outcomes Measurement Information System (PROMIS) Fatigue Short Form 7a.^{37, 38} This survey instrument is one of a family of Patient Reported Outcome measures developed by the National Institutes of Health (See <http://www.healthmeasures.net>). The PROMIS measures are universally-relevant, and can be applied to a variety of healthy populations or any population of those with a disease or chronic conditions. To facilitate this universal use, normative values have been created for PROMIS scores. Scores are converted to T-Scores, which are based on a representative sample of the US population. This allows results to be interpreted relative to a normative values in the absence of a control group.³⁹ The seven item short form includes questions about subjective feelings of tiredness, energy level, and fatigue associated activity limitation. Raw scores range from 7 (a response of “Never” to all questions) to 35 (a response of “Always” to all questions). We converted raw scores to T-scores using the scoring manual provided. A T-score of 50 represents an average level of fatigue for US adults and a T-score of 60 represents a fatigue level that is one standard deviation worse than average.

Activity Level Assessment

We used the UCLA activity score to assess subjects’ activity levels.⁴⁰ The UCLA activity score assesses self-reported activity level ranging from a score of 1 – “Wholly inactive; dependent on others; cannot leave residence” to 10 “Regularly participate in impact sports such as jogging, tennis, skiing, acrobatics, ballet, heavy labor, or backpacking”.

The UCLA activity score has been validated in THR populations.⁴¹

Statistical Analysis

Hypothesis testing was done using SPSS software V.24 (IBM SPSS Statistics for Windows, Version 24.0. Armonk, NY: IBM Corp). To test the associations among abductor torque, self-reported fatigue, and UCLA scores and to test whether or not fatigue mediated the association between abductor torque and UCLA scores, we conducted a series of linear regression models following the three-step Baron and Kenny method of evaluating mediation.^{42, 43} In order for fatigue to be considered a mediator in our conceptual model (Figure 1) the following conditions must be met: (1) the effect of abductor torque (the independent variable) on activity level (the dependent variable) is significant; (2) the path from abductor torque (the independent variable) to fatigue (the mediator) is significant; and (3) the path from fatigue (the mediator) to activity level (the dependent variable) is significant and the effect of abductor torque (the independent variable) is smaller in the presence of fatigue (the mediator). This method relies on an accurate conceptual model. Therefore we also tested two alternative models in which abductor torque was assumed to be the dependent variable, and in which abductor torque was considered to be the mediator.

Results

As a group, subjects reported “moderate” levels of physical activity based on UCLA scores (Table 1), as indicated by a mean score of 6. However, the most common response was a

score of 3 – “sometimes participates in mild activity...limited housework and limited shopping” (N = 4, 25%). Two subjects (12.5%) reported a UCLA score of 10 which indicates regular participation in impact sports. There were significant associations among UCLA scores, fatigue T-scores, and peak isometric abductor torque (Figure 2). Because of past studies that have suggested a link between fatigue and BMI, we assessed these correlations and found that BMI was associated with neither fatigue ($R = 0.188$, $p = 0.454$) nor UCLA scores ($R = -0.186$, $p = 0.459$).

For the first step of the mediation analysis, we evaluated the association between abductor torque and fatigue. There was evidence of a linear association ($\text{adj } R^2 = 0.223$, $F = 5.32$, $p = 0.037$). Subjects with lower abductor torque reported higher levels of fatigue (Table 2, Step 1). This association satisfied the first requirement for mediation. For the second step, we assessed the association between abductor torque and UCLA Activity Scores. There was evidence of a linear relationship ($\text{adj } R^2 = 0.452$, $F = 13.4$, $p = 0.003$). Subjects with higher abductor torque reported higher activity levels (Table 2, Step 2). The final model included both abductor torque and fatigue as independent variables and UCLA score as the dependent variable. The full model was statistically significant ($\text{adj } R^2 = 0.420$, $F = 6.4$, $p = 0.011$). However the coefficient for fatigue was not statistically significant (Table 2, Step 3). In other words, fatigue did not predict activity level in the presence of abductor torque. This indicated that fatigue did not mediate the association. Hip abductor torque was the best predictor of activity level (Figure 2a).

Finally, the evaluation of alternative models did not indicate that pathways other than the one hypothesized were more likely to be correct (Table 3). The final models and their individual steps agreed with the original model. Fatigue, abductor torque, and UCLA scores were statistically associated with each other, and the relationships did not change no matter which variables were considered independent, dependent, or mediator.

Discussion

The purpose of this study was to evaluate the associations among fatigue, abductor strength, and self-reported activity level in people with THR. The rationale was that a better understanding of unique factors associated with activity levels after THR will build a foundation for interventions that may increase physical activity and reduce health risks. We hypothesized that both lower abductor torque and higher fatigue are associated with lower UCLA scores. This hypothesis was supported. We further hypothesized that low abductor torque limits physical activity through an effect on fatigue levels (i.e. that fatigue mediates the association). Our results did not support this hypothesis. Although higher reported fatigue was associated with both lower abductor torque and lower UCLA scores, the analysis did not provide evidence for mediation. As in other studies,^{4, 5, 7} as a group subjects reported “moderate” levels of physical activity, with activity levels that ranged from 3 (“sometimes participates in mild activities”) to the highest score 10. Higher abductor torque was consistently associated with higher activity levels in all regression models.

It is important to note that the direction of the associations cannot be determined from our analysis. It is possible that higher abductor strength is a consequence of higher activity,

rather than a requirement for higher activity. Longitudinal studies are needed to determine whether or not improving abductor strength would improve activity levels in people with THRs. In either case, we speculate that a minimum level of abductor strength may be required to participate in moderate activity. The abductor torque in our subject group was in line with published data: ^{30, 34} using similar methodology, Judd and colleagues reported a mean peak isometric torque of 0.85 Nm/kg for control subjects and 0.88 Nm/kg for postoperative THR patients. ^{30, 34} In our subjects, the eight subjects with abductor torque at or above this normal value had higher UCLA scores (mean 8) than the other eight, whose abductor torque was below normal (mean 4). Moreover, no subjects with abductor torque values below normal had UCLA scores above 6. Future work in this area may lead to benchmarks for postoperative strength, such as those previously proposed for postoperative gait mechanics.⁴⁴

A somewhat surprising finding was that on average, these participants were not more fatigued than a general population of US adults. We expected, based on the OA literature, that subjects in this study would report significant levels of fatigue. Instead, all but 5 subjects had fatigue T-scores within one standard deviation of 50, the normed value based on a US population. This is not to say that fatigue is not important. Looking at these data another way, we see that 44% of participants did have more fatigue than “normal”. Moreover, the fact that there was a statistically significant association between abductor torque and fatigue, and between fatigue and activity level suggests that the variability in fatigue levels has clinical importance. We again note, however, that neither the direction of the associations nor a causal pathway can be inferred from the present analysis. In addition, the influence of fatigue on activity levels could come from other factors. Egerton and colleagues found that BMI altered the association between fatigue and physical activity in a healthy elderly cohort.⁴⁵ In our study, however, BMI was not associated with either fatigue or UCLA scores. It is possible that factors related to having a THR or a history of osteoarthritis, such as lower hip strength, poorer aerobic conditioning, or residual osteoarthritis-associated functional impairments are more important than BMI.

There were several limitations of this study that can guide future research. First, the sample size was relatively small, although we note that the sample size is in line with other biomechanical studies. To partially mitigate the effect of the sample size, we used a bootstrapping procedure to generate confidence intervals around the descriptive data provided in table 1,^{49, 50} and reported confidence intervals around estimates provided in tables 2 and 3. Larger studies are needed to more fully assess the potential combined influence of fatigue and abductor weakness, as well as other factors such as pain and sex, on activity level. Sex may be a particularly important issue for future work as the women in our study reported slightly lower UCLA scores than the men (Table 1). Second, the UCLA Activity Scores does not offer a quantitative assessment or specific information about the types of activities undertaken by patients. Accelerometer-based activity monitors would offer objective data of quantity and intensity of physical activity. However, the UCLA score has been shown to be correlated with objective measures of activity,⁴⁰ and is widely used in research. Information gleaned from this self-appraisal may also be more analogous to how activity would be assessed during a clinical encounter – objective physical activity measurement is not yet routine in clinical settings. Finally, it is important to note that there

are many other intrinsic and extrinsic factors that are associated with physical activity and may be impaired after THR. For example, fitness is associated with attaining higher levels of physical activity in older adults.⁴⁶ Horstmann and colleagues reported that cardiorespiratory fitness does not return to that of control subjects by 6 months after THR.⁴⁷ It is therefore possible that poor general fitness after THR in some people could also contribute to lower rates of participation in the higher levels of physical activity that are represented by higher UCLA scores. Indeed, in a recent case-series of two subjects seen after discharge from conventional physical therapy, aerobic exercise was a key part of a novel rehabilitation intervention that was designed in part to achieve higher levels of physical activity.⁴⁸ Notably, both self-reported fatigue and self-reported activity improved.

This analysis determined that both abductor torque and fatigue are associated with activity level in a group of community dwelling people 1-5 years after THR. Although we cannot infer causality from this cross-sectional study, the findings indicate a potential role for both the energy restriction model and the activity avoidance model. Future work can build from either or both of these models to target the unique factors associated with low physical activity levels in people with THRs.

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Hypothesized associations among hip abductor strength,
fatigue, and activity levels

Figure 1.
Proposed model in which fatigue mediates the relationship between hip abductor strength and activity level.

Figure 2.

Scatterplots illustrating the associations evaluated. There were statistically significant associations among UCLA Activity Scores, Fatigue T-Scores, and Peak Isometric Abductor Torque. Abductor Torque was the strongest predictor of UCLA Activity Scores.

Table 1

Mean, Standard Deviation, 95% confidence intervals (generated using a bootstrapping procedure) and range for subject characteristics.

	All (N = 16)	Men (N = 5)	Women (N = 11)
Age (years)	56.8 SD 8.3 (53.0, 61.0) 45 – 76	59.4 SD 7.5 (52.6, 64.6) 47–67	55.6 SD 8.8 (51.1, 61.2) 45–76
BMI (kg/m²)	30.9 SD 7.7 (27.5, 34.9) 19.5 – 44.7	27.0 SD 4.3 (23.5, 30.3) 20.8–32.6	32.7 SD 8.3 (27.7, 37.4) 19.4–44.7
Time since surgery (months)	23.8 SD 10.2 (19.1, 28.8) 12 – 48	26.6 SD 14.0 (16.9, 37.8) 12–48	22.6 SD 2.7 (17.9, 27.5) 13–40
UCLA Activity Score	6 SD 2 (5, 7) 3 – 10	6 SD 2 (5, 7) 4–8	6 SD 3 (4, 7) 3–10
Peak Isometric Hip Abductor Torque (Nm/kg)	0.9 SD 0.4 (0.7, 1.1) 0.3 – 1.6	1.0 SD 0.3 (0.8, 1.2) 0.7–1.4	0.9 SD 0.4 (0.6, 1.1) 0.3–1.6
Fatigue T Score	48.0 SD 7.1 (44.5, 51.2) 36.9 – 56.4	48.4 SD 6.0 (43.1, 53.5) 39.6–56.4	47.8 SD 7.8 (43.4, 52.0) 36.9–56.4

Results of linear regression model indicate that fatigue does not mediate the association between abductor muscle strength (peak isometric torque) and activity level (UCLA Activity Score). Specifically, step 3 indicates that fatigue does not explain UCLA activity score in the presence of abductor strength.

Table 2

Analysis Step	Dependent Variable	Independent Variable	Adjusted R ²	Model F (p value)	Regression Coefficient (95% Confidence Interval)	p value
1	Fatigue Score	Peak Isometric Abductor Torque	0.223	5.32	-10.5 (-20.2, -0.7)	p = 0.037
2	UCLA Activity Score	Peak Isometric Abductor Torque	0.452	13.4	4.7 (2.0, 7.5)	p = 0.003
3	UCLA Activity Score	Peak Isometric Abductor Torque	0.420	6.4	4.4 (1.0, 7.9)	p = 0.014
		Fatigue Score		p = 0.011	-0.03 (-0.2, 0.14)	p = 0.724

Table 3

Results of linear regression models representing alternative pathways among the potential independent, dependent, and mediator variables. Neither alternative model was supported.

Alternative Model 1: Does activity level mediate the association between fatigue and abductor strength?					
Analysis Step	Dependent Variable	Independent Variable	Adjusted R ²	Model F (p value)	Regression Coefficient (95% Confidence Interval) p value
1	UCLA Activity Score	Fatigue Score	0.263	7.075 p = 0.017	-0.2 (-0.3, -0.04) p = 0.017
2	Peak Isometric Abductor Torque	Fatigue Score	0.223	5.301 p = 0.037	-0.03 (-0.05, -0.002) p = 0.037
3	Peak Isometric Abductor Torque	Fatigue Score	0.482	7.966 p = 0.006	-0.014 (-0.036, 0.008) p = 0.202
		UCLA Activity Score			0.086 (0.020, 0.151) p = 0.014
Alternative Model 2: Does abductor strength mediate the association between activity level and fatigue?					
Analysis Step	Dependent Variable	Independent Variable	Adjusted R ²	Model F p value	Regression Coefficient (95% Confidence Interval) P value
1	Peak Isometric Abductor Torque	UCLA Activity Score	0.452	13.364 p = 0.003	-5.8 (-11.7, -1.3) p = 0.003
2	Fatigue Score	UCLA Activity Score	0.124	3.121 p = 0.099	-1.3 (-2.8, 0.27) p = 0.099
3	Fatigue Score	UCLA Activity Score	0.171	2.551 p = 0.116	-0.2 (-2.4, 1.7) p = 0.724
		Peak Isometric Abductor Torque			-5.3 (-23.0, 5.4) p = 0.202