

# Association of Quadriceps Strength and Psychosocial Factors With Single-Leg Hop Performance in Patients With Meniscectomy

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**Background:** Clinicians use the single-leg hop test to assess readiness for return to sports after knee injury. Few studies have reported the results of single-leg hop testing after meniscectomy. Additionally, the contributions of impairments in quadriceps strength and psychosocial factors to single-leg hop performance are unknown.

**Purpose:** To compare single-leg hop performance (distance and landing mechanics) between limbs and to examine the association of single-leg hop performance with quadriceps strength and psychosocial factors in patients with meniscectomy.

**Study Design:** Descriptive laboratory study.

**Methods:** A total of 22 subjects who underwent meniscectomy for traumatic meniscal tears received either standard rehabilitation alone or with additional quadriceps strengthening. Testing was conducted immediately postrehabilitation and at 1 year postsurgery. A single-leg hop test was performed bilaterally, and hop distance was used to create a hop symmetry index. Landing mechanics (peak knee flexion angle, knee extension moment, and peak vertical ground-reaction force) were analyzed with a motion-capture system and a force plate. An isokinetic dynamometer (60 deg/s) assessed knee extensor peak torque and rate of torque development (RTD<sub>0-200ms</sub> and RTD<sub>0-peak torque</sub>). Questionnaires assessed fear of reinjury (Tampa Scale for Kinesiophobia [TSK-11]) and self-efficacy (Knee Activity Self-Efficacy [KASE]).

**Results:** Rehabilitation groups did not significantly differ in single-leg hop performance; therefore, groups were combined for further analyses. The mean hop symmetry index was 88.6% and 98.9% at postrehabilitation and 1 year postsurgery, respectively. Compared with the nonsurgical limb, the surgical limb showed decreased peak knee flexion angle at postrehabilitation and decreased knee extension moment at 1 year postsurgery. The hop symmetry index was positively associated with peak torque, RTD<sub>0-200ms</sub>, and the KASE score at postrehabilitation. Moreover, at postrehabilitation, the peak knee flexion angle was positively associated with peak torque and RTD<sub>0-200ms</sub>, and the knee extension moment was positively associated with RTD<sub>0-200ms</sub>. At 1 year postsurgery, peak knee flexion angle and knee extension moment were both positively associated with peak torque, RTD<sub>0-200ms</sub>, and RTD<sub>0-peak torque</sub>.

**Conclusion:** Although the hop symmetry index could be considered satisfactory for returning to sports, asymmetries in landing mechanics still exist in the first year postmeniscectomy. Greater quadriceps strength was associated with greater single-leg hop distance and better landing mechanics at both postrehabilitation and 1 year postsurgery. Knee activity self-efficacy was the only psychosocial factor associated with single-leg hop performance and isolated to a positive association with single-leg hop distance at postrehabilitation.

**Clinical Relevance:** Rate of development is not typically measured in the clinic but can be an additional quadriceps measure to monitor for single-leg hop performance. Quadriceps strength and psychosocial factors appear to have separate influence on single-leg hop performance after meniscectomy, which has implications for developing appropriate interventions for optimal single-leg hop performance.

**Keywords:** knee; hop test; biomechanics; rate of torque development; confidence; self-efficacy

Arthroscopic partial meniscectomy is a common surgical treatment for irreparable meniscal tears.<sup>3</sup> While isolated meniscectomy produces less tissue morbidity than other

knee surgeries, such as anterior cruciate ligament (ACL) reconstruction, the effects of meniscectomy on knee function may be overlooked. For example, only 44% of patients with meniscectomy participate in sports at the preinjury level at 3 years after surgery.<sup>46</sup> Unresolved physical or psychosocial impairments can limit knee function after knee injury and surgery.<sup>4,28</sup> Therefore, it is important to identify

The Orthopaedic Journal of Sports Medicine, 4(12), 2325967116676078  
DOI: 10.1177/2325967116676078  
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and address physical and psychosocial impairments to maximize knee rehabilitation functional outcomes.

The single-leg hop test is used in lower extremity rehabilitation to assess knee function and determine a patient's readiness to return to sports participation.<sup>21</sup> The typical measure of single-leg hop performance is hop distance. Single-leg hop distance is often represented by a hop symmetry index, which is the distance on the surgical limb normalized to that of the nonsurgical limb.<sup>43</sup> Quality of movement is also an important aspect of single-leg hop performance because altered movement patterns may increase the risk of future knee injury.<sup>40</sup> Few studies have reported on the hop symmetry index or landing mechanics after meniscectomy.<sup>15</sup>

Quadriceps muscle weakness is prevalent after knee injury<sup>19,39</sup> and has the potential to affect single-leg hop performance. Common quadriceps strength measures are peak knee extensor torque normalized to body weight or a quadriceps symmetry index.<sup>54</sup> The association of peak knee extensor torque or quadriceps symmetry index with single-leg hop performance is inconclusive.<sup>||</sup> Rate of torque development is another measure of quadriceps strength.<sup>24,29</sup> Explosive movements, such as jumping and sprinting, require muscle strength developed within 200 ms.<sup>30,34</sup> Therefore, the knee extensor rate of torque development may be a more relevant measure of quadriceps strength relative to single-leg hop performance.<sup>25,53</sup>

Kinesiophobia, or fear of movement/reinjury, and self-efficacy are 2 psychosocial factors with known influences on knee rehabilitation functional outcomes.<sup>4,8</sup> Fear of movement/reinjury is increased after knee injury<sup>47</sup> and linked to lower self-reported knee function and return-to-sports rate after ACL reconstruction.<sup>6,7,31,32,52</sup> Knee activity self-efficacy is associated with lower self-reported knee function in patients after knee injury<sup>26</sup> and predicts single-leg hop performance at 6 weeks and 1 year after ACL reconstruction.<sup>49,50</sup> Both fear of movement/reinjury and self-efficacy have the potential to affect single-leg hop performance.

The purpose of this study was to compare single-leg hop performance (hop distance and landing mechanics) between limbs in patients with meniscectomy and examine the association of single-leg hop performance with quadriceps strength and psychosocial factors. We hypothesized that the surgical limb would show lower hop distance and altered landing mechanics compared with the nonsurgical limb at 6 weeks and 1 year after meniscectomy, and that decreased quadriceps strength and altered psychosocial

factors would be associated with poorer single-leg hop performance.

## METHODS

This study was a secondary analysis of data collected in a randomized controlled trial study comparing the effects of standard rehabilitation alone or with additional quadriceps muscle strengthening on knee function and articular cartilage structure after meniscectomy (ClinicalTrials.gov: NCT01879852).

### Subjects

Eligible subjects were patients with traumatic-onset meniscal tears who underwent partial meniscectomy. The inclusion criteria were age from 15 to 35 years, meniscectomy performed within 12 months of injury, and meniscal tear confirmed at the time of surgery. Exclusion criteria were bilateral injury, concomitant ligamentous injury, previous knee injury, articular cartilage defect greater than grade 2 on Outerbridge scale confirmed at the time of surgery, patellofemoral joint pain, and lower extremity mechanical axis  $>5^\circ$  valgus or varus. All surgical procedures were performed by 3 board-certified orthopaedic surgeons. All subjects gave written consent or assent (minor subjects) to participate in this study on a form approved by the institutional review board.

### Rehabilitation

After surgery, subjects were randomly assigned to receive either standard rehabilitation alone or with additional quadriceps strengthening. A computer-generated randomization scheme was created and balanced to ensure equal allocation to treatment group with stratification by sex. Treatment group assignment was maintained by an investigator and provided to treating physical therapists after subject eligibility was confirmed at the time of surgery.

Rehabilitation began within 1 week postsurgery. Standard rehabilitation consisted of interventions to address typical impairments after meniscectomy and included cryotherapy, compression, elevation, knee range of motion, lower extremity strengthening, lower extremity stretching, and balance exercises. In the additional quadriceps strengthening group, subjects also received neuromuscular electrical stimulation to the quadriceps and eccentric overload during quadriceps strengthening exercises. Rehabilitation was administered 2 times per week for 6 weeks. Two licensed physical therapists supervised the application of all rehabilitation interventions.

<sup>||</sup>References 10, 15, 22, 27, 33, 41, 42, 44, 45.

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One or more of the authors has declared the following potential conflict of interest or source of funding: This study was supported by the National Institutes of Health grant K01-HD052713.

Ethical approval for this study was obtained from the University of Florida Institutional Review Board (IRB Protocol #578-2007).

## Testing Overview

Testing was performed immediately after rehabilitation and at 1 year postsurgery. Demographic information, single-leg hop distance and landing mechanics, quadriceps strength measures, and psychosocial questionnaire responses were collected.

## Demographic Information

Demographic information included sex, age, height, weight, dominant limb, time from injury to surgery, and location of the meniscectomy. Additionally, return-to-sports status was evaluated with the question "Have you returned to the same level of sports or recreational activities as before your injury?" Subjects who reported that they had not returned to preinjury sports or recreational activity participation were asked to select the primary reason from the following options: pain, swelling, fear of injury or lack of confidence, knee instability, muscle weakness, not yet cleared from doctor to return to sports, too little time to participate or had a change in lifestyle, and other.

## Single-Leg Hop Distance

Subjects stood on the nonsurgical limb and performed a maximum-effort forward hop, landing on the same limb. Several practice trials were performed until there was no increase in hop distance, then 3 test trials were performed. The test was repeated on the surgical limb. Distance was recorded, averaged across trials, and used to calculate a hop symmetry index:  $(\text{average hop distance on the surgical limb} / \text{average hop distance on the nonsurgical limb}) \times 100\%$ .

## Single-Leg Hop Landing Mechanics

Retroreflective markers for tracking lower extremity movement were placed on the sacrum, bilateral anterior superior iliac spines, bilateral heel of the shoes, bilateral head of the fifth metatarsals, and bilateral top of the second toe. Thermoplastic shells with 3 markers affixed to the surfaces were attached to the bilateral thighs and shanks. Marker positions were recorded at 200 Hz with an 8-camera 3-dimensional motion capture system (Motion Analysis Corp). Synchronized force data were sampled at 1200 Hz using a 6-component force plate (Advanced Mechanical Technology). The starting point for the single-leg hop was set at 80% of the mean maximal hop distance because pilot testing showed subjects could reliably hop this distance and land in the center of the force plate. Subjects performed at least 3 practice trials, and 3 successful trials were recorded. A successful trial was defined as the subject landing in the center of the force plate and holding the landing position for at least 3 seconds.

Kinematic and kinetic data were analyzed during the landing phase using Visual 3D (version 5.01; C-Motion Inc) and a custom written software program (LabVIEW 2011; National Instruments). Marker positions and force data were low-pass filtered using a second-order Butterworth filter at 6 and 15 Hz, respectively.

Kinematic data of 7 subjects at postrehabilitation and 1 subject at 1 year postsurgery were erroneously sampled at 120 Hz. Kinetic data of 7 subjects at postrehabilitation were incorrectly sampled at 600 and 720 Hz, and that of 2 subjects at 1 year postsurgery were incorrectly sampled at 720 and 1000 Hz. Data for these subjects were up-sampled to 200 Hz for kinematic data and 1200 Hz for kinetic data (cubic spline interpolation) to match the sampling rate of other subjects. The variables of interest were peak knee flexion angle, knee extension moment normalized to body mass, and peak vertical ground-reaction force normalized to body weight.

## Quadriceps Strength

Subjects were seated and stabilized in an isokinetic dynamometer (Biodex System3; Biodex Corp) with the hips and knees flexed at 90° and the back supported. The knee extension-flexion axis was approximated by aligning the dynamometer rotational axis with the lateral femoral condyle. The shin pad was attached 2 finger-widths above the lateral malleolus. The testing speed was selected at 60 deg/s,<sup>14</sup> and the range of motion was 10° to 100° of knee flexion (0° was defined as full extension). Before testing, subjects performed 3 practice trials at 50% of maximal effort to familiarize themselves with the testing apparatus. After 1 minute of rest, subjects performed 3 maximal effort trials with verbal encouragement and visual feedback.

Knee extensor torque data were recorded at a sampling rate of 100 Hz and analyzed using custom-written software (LabVIEW). Knee extensor torque data were filtered with a second-order, low-pass Butterworth filter with a cutoff frequency of 6 Hz. Onset of force was defined as the time when knee extensor torque exceeded the baseline level by 7.5 N·m.<sup>1</sup> The variables of interest included peak torque, rate of torque development from 0 to 200 ms (RTD<sub>0-200ms</sub>), and rate of torque development from 0 to peak torque (RTD<sub>0-peak torque</sub>). Peak torque (in N·m/kg), representing the greatest torque value of the trial, was measured. The RTD variables (in N·m/s/kg) were computed from torque onset to the given time points (ie, 200 ms and peak torque) by taking the slope of the torque-time curve every 10 ms and averaging across the entire interval.

## Psychosocial Factors

Fear of movement/reinjury was measured using the shortened version of the Tampa Scale for Kinesiophobia (TSK-11). The TSK-11 is an 11-item questionnaire that eliminates psychometrically poor items from the original TSK to create a shorter questionnaire with comparable internal consistency.<sup>55</sup> Items related to somatic focus and activity avoidance are scored from 1 (*strongly disagree*) to 4 (*strongly agree*). Total scores ranges from 11 to 44, and higher scores indicate greater pain-related fear of movement/reinjury. Test-retest reliability coefficients for the TSK-11 have been reported to be 0.93 in patients with low back pain.<sup>17</sup> The TSK-11 is also a valid measure of fear of movement/reinjury in the late postsurgical phase after ACL reconstruction.<sup>16</sup>

TABLE 1  
Demographic Information (N = 22 Subjects)<sup>a</sup>

Sex, n	
Male	20
Female	2
Age, y	19.4 ± 3.0
Height, cm	178.0 ± 9.3
Weight, kg	87.5 ± 26.1
Time from injury to surgery, mo	3.3 ± 2.5
Side of meniscectomy, n	
Medial meniscectomy	7
Lateral meniscectomy	15

<sup>a</sup>Data are reported as mean ± SD unless otherwise indicated.

Self-efficacy was measured with a 10-item Knee Activity Self-Efficacy (KASE) questionnaire,<sup>5,26</sup> developed by the authors based on a published questionnaire<sup>49</sup> and clinical experience. Items related to the confidence in the ability to perform functional activities are scored from 1 (*strongly disagree*) to 10 (*strongly agree*). Total scores range from 0 to 100, and higher scores indicate greater self-efficacy for knee activity. Although not yet validated, the test-retest reliability for the KASE questionnaire was analyzed in 53 patients with ACL reconstruction who completed the questionnaire at 8 and 9 weeks postsurgery. The intraclass correlation coefficient was 0.85.

### Statistical Analysis

Statistical analyses were conducted with commercial software (SPSS 20; IBM Corp). Descriptive statistics were generated for all measures. Two-way (limb × time) analysis of variance examined effects of limbs and time on landing mechanics variables (peak knee flexion angle, knee extension moment, and peak vertical ground-reaction force). When significant interactions or main effects were found, paired-sample *t* tests were used to compare landing mechanics variables between limbs. An alpha level of 0.008 (0.05/6) was used to account for multiple comparisons. Pearson correlation coefficients determined the association of single-leg hop performance (hop symmetry index and landing mechanics variables) with quadriceps strength variables and psychosocial factors. An alpha level of 0.05 was used for the correlation analyses.

Exploratory analyses with Mann-Whitney *U* test examined differences in the hop symmetry index and landing mechanics based on return-to-sports status, with an alpha level of 0.05 set for significance.

## RESULTS

A total of 22 subjects participated. Demographic information can be found in Table 1. Ten subjects were randomized to the standard rehabilitation group, and 12 subjects to the additional quadriceps strengthening group. There were no significant differences in single-leg hop performance (hop symmetry index and landing mechanics) between rehabilitation groups; thus, groups were combined for further

TABLE 2  
Landing Mechanics at Postrehabilitation  
and 1 Year Postsurgery<sup>a</sup>

	Surgical Limb	Nonsurgical Limb
Peak knee flexion angle, deg		
Postrehabilitation	42.8 ± 10.2 <sup>b</sup>	50.0 ± 9.0
1 year postsurgery	48.6 ± 10.4	53.0 ± 9.1
Knee extension moment, N·m/kg		
Postrehabilitation	1.0 ± 0.6	1.3 ± 0.6
1 year postsurgery	1.3 ± 0.4 <sup>c</sup>	1.6 ± 0.5
Peak vertical ground-reaction force, BW		
Postrehabilitation	2.4 ± 0.6	2.4 ± 0.6
1 year postsurgery	2.5 ± 0.6	2.5 ± 0.6

<sup>a</sup>Data are reported as mean ± SD. BW, body weight.

<sup>b</sup>Statistically significant difference compared with nonsurgical limb (*P* = .003).

<sup>c</sup>Statistically significant difference compared with nonsurgical limb (*P* = .007).

analyses. The surgical limb was the dominant limb in 12 subjects. There were no significant differences in landing mechanics variables between these 12 subjects and the remaining subjects. The mean time from injury to surgery was 3.3 months, with 19 subjects within 6 months and 3 subjects longer than 6 months. At postrehabilitation, 18 subjects (82%) reported that they had not returned to same level of sports or recreational activities as before surgery. The primary reason for not returning to preinjury activities included not yet cleared from doctor to return to sports (*n* = 11), fear of injury or lack of confidence (*n* = 4), and knee impairments (swelling and muscle weakness; *n* = 3). Four subjects (18%) reported that they had not returned to the same level of sports or recreational activities as before their injury at 1 year postsurgery. The primary reason for not returning to preinjury activities at 1 year postsurgery included fear of injury or lack of confidence (*n* = 2), swelling (*n* = 1), and other (social reason; *n* = 1).

The hop symmetry index was 88.6% at postrehabilitation and 98.9% at 1 year postsurgery. No interaction of limb and time was noted for peak knee flexion angle ( $F_{1,21} = 1.445$ ; *P* = .243), however, there were significant main effects of limb (*P* = .001) and time (*P* = .002). Compared with the nonsurgical limb, the surgical limb showed decreased peak knee flexion angle postrehabilitation (*P* = .003). No interaction of limb and time was noted for knee extension moment ( $F_{1,21} = 0.483$ ; *P* = .495), but significant main effects of limb (*P* = .004) and time (*P* = .006) were observed. Compared with the nonsurgical limb, the surgical limb showed decreased knee extension moment at 1 year postsurgery (*P* = .007). For peak vertical ground-reaction force, none of the interaction ( $F_{1,21} = 1.751$ ; *P* = .200) or main effects (limb, *P* = .751; time, *P* = .578) was significant (Table 2).

Quadriceps strength variables and psychosocial factors questionnaire scores at postrehabilitation and 1 year postsurgery are listed in Table 3. At postrehabilitation, the hop

TABLE 3  
Quadriceps Strength and Psychosocial Factors  
at Postrehabilitation and 1 Year Postsurgery<sup>a</sup>

	Surgical Limb	Nonsurgical Limb
Peak torque, N/kg		
Postrehabilitation	1.9 ± 0.6	2.4 ± 0.4
1 year postsurgery	2.4 ± 0.5	2.5 ± 0.4
RTD <sub>0-200 ms</sub> , N·m/s·kg		
Postrehabilitation	6.3 ± 2.0	8.0 ± 1.8
1 year postsurgery	7.9 ± 2.1	8.0 ± 1.7
RTD <sub>0-peak torque</sub> , N·m/s·kg		
Postrehabilitation	3.5 ± 1.5	4.3 ± 1.0
1 year postsurgery	4.0 ± 1.5	4.5 ± 1.3
	Score	
TSK-11		
Postrehabilitation	19.7 ± 5.3	
1 year postsurgery	17.5 ± 4.6	
KASE		
Postrehabilitation	79.7 ± 17.1	
1 year postsurgery	92.5 ± 9.7	

<sup>a</sup>Data are reported as mean ± SD. BW, body weight; KASE, Knee Activity Self-Efficacy questionnaire; RTD, rate of torque development; TSK, Tampa Scale for Kinesiophobia.

symmetry index was positively associated with peak torque, RTD<sub>0-200ms</sub>, and KASE score; peak knee flexion angle was positively associated with peak torque and RTD<sub>0-200ms</sub>; and knee extension moment was positively associated with RTD<sub>0-200ms</sub>. No significant associations were found between landing mechanics variables and psychosocial factor questionnaire scores (Table 4). At 1 year postsurgery, peak knee flexion angle and knee extension moment were positively associated with peak torque, RTD<sub>0-200ms</sub>, and RTD<sub>0-peak torque</sub>. No significant associations were found between hop symmetry index with quadriceps strength variables and psychosocial factor questionnaire scores. Additionally, no significant associations were found between landing mechanics variables and psychosocial factor questionnaire scores (Table 5).

The exploratory analyses revealed that at postrehabilitation, no significant differences in hop symmetry index and landing mechanics were observed based on return-to-sports status (Table 6). At 1 year postsurgery, subjects who returned to preinjury activity levels had greater knee extension moment ( $P = .014$ ) than those who did not, but no significant difference in hop symmetry index was observed based on return-to-sports status.

## DISCUSSION

This study compared single-leg hop performance between limbs and examined its association with quadriceps strength and psychosocial factors. Results revealed that asymmetrical landing mechanics existed after meniscectomy rehabilitation and 1 year after surgery despite a clinically acceptable hop symmetry index. Quadriceps

strength, including peak torque and rate of torque development, was associated with the hop symmetry index and landing mechanics. The KASE score was only associated with the hop symmetry index. Collectively, these findings suggest that landing mechanics are impaired after meniscectomy. In addition, quadriceps strength and psychosocial factors appeared to have separate influence on single-hop performance.

The mean hop symmetry index at postrehabilitation was 88.6%, which is close to the 90% value that has been recommended for returning to sports.<sup>51</sup> However, asymmetrical landing mechanics still existed. The injured limb showed 14% lower peak knee flexion angle and 18% lower knee extension moment than the noninjured limb. On the other hand, peak vertical ground-reaction force was not different between limbs, which suggests that reduced knee extension moment may be compensated for by increasing the moment at the hip and ankle.<sup>12,18,38</sup> Landing mechanics improved from postrehabilitation to 1 year postsurgery, but the surgical limb still exhibited 8% lower peak knee flexion angle and 10% lower knee extension moment than the nonsurgical limb. By 1 year after meniscectomy, 82% of subjects participated in sports at the preinjury level. The findings suggest that impaired landing mechanics may last beyond the time frame when returning to sports is allowed. A reduced knee extension moment can potentially influence return-to-sports outcomes at 1 year postsurgery, and unresolved asymmetries in landing mechanics may increase the risk of future injury.<sup>23,40</sup> Landing mechanics should therefore be assessed and addressed in patients with meniscectomy. For example, clinically available means for landing mechanics analysis, such as 2-dimensional (2D) image/video-based techniques,<sup>9,35</sup> might be useful to assess knee flexion angle, and the deficits in knee flexion angle can be addressed with oral and visual feedback provided by the physical therapist and the 2D image/video, respectively.<sup>11,13,37</sup>

Greater knee extensor peak torque and rate of torque development were associated with better quantity and quality of single-leg hop performance. The magnitude of association was greater for peak torque and RTD<sub>0-200ms</sub>. Our preliminary data showed that the time from initial contact to peak knee flexion during landing phase was less than 200 ms. It may be reasonable that the single-leg hop performance is influenced to a greater extent by rate of torque development in the first 200 ms than in the longer interval to peak torque. The findings suggest that although peak torque is more commonly assessed in the clinic, it may be beneficial to also monitor rate of torque development and provide appropriate interventions to improve single-leg hop performance.

Higher self-efficacy for knee activity was associated with greater hop symmetry index, which is consistent with self-efficacy theory.<sup>2</sup> Our study provides additional evidence for the relevance of self-efficacy on functional performance in knee injury populations.<sup>7,26,49,50</sup> However, we cannot establish a cause-effect relationship between knee self-efficacy and hop symmetry index. Potentially, inadequate rehabilitation of the knee postmeniscectomy could affect single-leg hop distance and lead to low knee self-efficacy.

TABLE 4  
Association of Quadriceps Strength and Psychosocial Factors With Single-Leg Hop Performance at Postrehabilitation<sup>a</sup>

	Peak Torque	RTD <sub>0-200 ms</sub>	RTD <sub>0-peak torque</sub>	Score	
				TSK-11	KASE
Single-leg hop index	0.57 <sup>b</sup>	0.57 <sup>b</sup>	0.11	0.03	0.40 <sup>b</sup>
Peak knee flexion angle	0.66 <sup>b</sup>	0.53 <sup>b</sup>	0.19	0.01	0.22
Knee extension moment	0.39	0.48 <sup>b</sup>	0.19	0.28	0.13
Peak vertical ground-reaction force	-0.13	-0.14	0.14	0.04	-0.10

<sup>a</sup>KASE, Knee Activity Self-Efficacy questionnaire; RTD, rate of torque development; TSK, Tampa Scale for Kinesiophobia.

<sup>b</sup>*P* < .05.

TABLE 5  
Association of Quadriceps Strength and Psychosocial Factors With Single-Leg Hop Performance at 1 Year Postsurgery<sup>a</sup>

	Peak Torque	RTD <sub>0-200 ms</sub>	RTD <sub>0-peak torque</sub>	Score	
				TSK-11	KASE
Single-leg hop index	0.23	0.36	0.30	-0.28	0.29
Peak knee flexion angle	0.73 <sup>c</sup>	0.64 <sup>b</sup>	0.52 <sup>b</sup>	0.19	0.23
Knee extension moment	0.47 <sup>b</sup>	0.60 <sup>b</sup>	0.56 <sup>b</sup>	0.09	0.38
Peak vertical ground-reaction force	0.33	0.12	0.23	0.01	-0.24

<sup>a</sup>KASE, Knee Activity Self-Efficacy questionnaire; RTD, rate of torque development; TSK, Tampa Scale for Kinesiophobia.

<sup>b</sup>*P* < .05.

<sup>c</sup>*P* < .001.

TABLE 6  
Single-Leg Hop Index and Landing Mechanics Based on Return-to-Sports Status<sup>a</sup>

	Returned to Sports	Did Not Return to Sports	<i>P</i> Value
Single-leg hop index, %			
Postrehabilitation	79.1 ± 18.7	90.7 ± 11.9	.141
1 year postsurgery	99.7 ± 6.4	95.1 ± 6.1	.386
Peak knee flexion angle, deg			
Postrehabilitation	44.9 ± 17.8	42.3 ± 8.5	.967
1 year postsurgery	48.1 ± 9.7	51.0 ± 14.5	.774
Knee extension moment, N·m/kg			
Postrehabilitation	0.8 ± 0.7	1.0 ± 0.5	.594
1 year postsurgery	1.4 ± 0.4	0.9 ± 0.2	.014 <sup>b</sup>
Peak vertical ground-reaction force, BW			
Postrehabilitation	2.3 ± 0.5	2.4 ± 0.7	.837
1 year postsurgery	2.5 ± 0.6	2.8 ± 0.2	.484

<sup>a</sup>Data are reported as mean ± SD. BW, body weight.

<sup>b</sup>Statistically significant difference between groups (*P* < .05).

Fear of movement/reinjury was not associated with single-leg hop index, which agrees with findings by Hartigan et al<sup>20</sup> and Lentz et al.<sup>32</sup> Fear of movement/reinjury was also not significantly associated with landing mechanics, although it has been associated with movement patterns in a low back pain population.<sup>48</sup> Thus, fear of movement/reinjury and self-efficacy are distinct constructs with specific influences on function after knee injury. Additional research is needed to understand if psychosocial impairments contribute to movement patterns after meniscectomy or other knee injury.

The strengths of this study include the longitudinal study design and the simultaneous examination of physical and psychosocial impairments to functional performance. This study has limitations that need to be addressed in future research. The number of subjects was relatively small, which limits our ability to perform multivariate analysis. The initial testing time point was before the majority of subjects had returned to sports, and the follow-up testing time point was relatively long. Most of our subjects attempted to resume sports participation; however, the level of exercise intensity and sports participation

were not tracked. Some patients might have been exposed to more sports activities than others, which should be considered when interpreting these results. Future studies would benefit from intermediate testing time points to better understand changes in single-leg hop performance after meniscectomy. Three subjects in this study were considered as having chronic tears.<sup>29</sup> There might be a possible neuromuscular adaptation for those with chronic tears. It should be noted that 2 of 3 subjects were in the standard rehabilitation group while 1 was in the additional quadriceps strengthening group, so any potential effect of chronicity was evenly distributed between groups. Additional quadriceps strengthening in the study did not appear to effectively overcome the deficits in single-leg hop performance. Future studies should explore other interventions, including visual or verbal feedback,<sup>36</sup> to improve single-leg hop performance. Finally, the study did not have a control group with no rehabilitation or home exercise only, so our results may not be applicable to patients with meniscectomy who receive fewer rehabilitation visits.

## CONCLUSION

Although the hop symmetry index was considered satisfactory for returning to sports as per current recommendations, asymmetries in peak knee flexion angle and knee extension moment during the landing phase of a single-leg hop were observed at 6 weeks and 1 year after meniscectomy. Greater quadriceps peak torque and rate of torque development were associated with greater single-leg hop distance and better landing mechanics. Knee activity self-efficacy was the only psychosocial factor associated with single-leg hop performance and isolated to a positive association with single-leg hop distance at postrehabilitation.

## ACKNOWLEDGMENT

The authors acknowledge Michael Moser, MD, Peter Indelicato, MD, Kevin Farmer, MD, Matt Walser, ATC, PA-C, and Chris Koenig, ATC, for assisting with patient recruitment; Susan Tillman, PT, SCS, CSCS, and Trevor Lentz, MPT, CSCS, for supervising the application of rehabilitation interventions; and Benjamin Fregly, PhD, for assisting with kinematic and kinetic data resampling.

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