Brake Reaction Time After Hip Arthroscopy for Femoroacetabular Impingement and Labral Tear

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Purpose: To determine if a difference exists in brake reaction time (BRT) before and after hip arthroscopy for femoroacetabular impingement (FAI) and labral tear compared with age- and gender-matched controls. **Methods:** Consecutive adult subjects undergoing primary hip arthroscopy were eligible for this prospective investigation. Individuals with symptomatic FAI and labral tear that underwent hip arthroscopy with minimum 8 weeks follow-up were included. BRT was measured using the RT-2S reaction time tester a maximum of 6 weeks preoperatively and every 2 weeks postoperatively for 8 weeks. Sit-to-stand test (STST) was measured at each BRT testing session. An age- and gender-matched control group without hip or lower extremity symptoms were selected and completed both BRT and STST. Continuous pre- and postoperative BRT values were compared with Mann-Whitney and analyses of variance. Association of BRT and STST tests was performed with Spearman correlation. An a priori sample size calculation determined that minimally 18 subjects per group (surgery group vs control group) were necessary to detect, with 80% power (difference of 0.2 seconds in BRT). **Results:** Nineteen subjects (age 37.1 $\pm$ 12.7 years, 10 women, 11 right hip) were analyzed. All subjects underwent arthroscopic labral repair and FAI correction. There was no difference between preoperative (604 $\pm$ 148 milliseconds [ms]) and postoperative (608 ms 2 weeks; 566 ms 4 weeks; 559 ms 6 weeks; 595 ms 8 weeks) BRT. There was no difference between controls and subjects at any time point. There was a strong negative correlation between BRT and STST preoperatively and at 4 and 6 weeks postoperatively and a moderate negative correlation at 2 weeks postoperatively. **Conclusions:** After hip arthroscopy for FAI and labral tear, BRT is not different from preoperative values or that of controls. In addition, BRT had a significant correlation with STST in the first 6 weeks after surgery. **Level of Evidence:** Level II, diagnostic, prospective.

The decision to return to driving after surgery has both legal and medical implications.[1] The safety of driving after surgery is highly multifactorial, depending on several patient medical and surgical factors. Although studies have investigated BRT after orthopaedic procedures of the lower extremity, few formal guidelines exist to help either the physician or the patient to determine when it is safe to return to driving after various lower extremity surgeries.[2-4] Brake reaction time (BRT) has been found to be one of the most important variables to evaluate safe driving and has been researched in the setting of various other orthopaedic procedures.[3-7] Most orthopaedic surgeons have recommended a return to driving at 4 to 6 weeks after surgery of the lower extremity.[8] The average BRT of nonoperative drivers varies widely from 552 to 2450 milliseconds (ms).[9]

Driving simulators may be used to measure BRT. However, simulators are costly and infrequently used in the clinical setting. Thus, there is specific interest in using alternative measures, such as a sit-to-stand-test (STST), to assess driving safety.[8] The STST measures the number of times a patient can rise from a sitting to a standing position in 10 seconds. The STST is strongly correlated with BRT after anterior cruciate ligament (ACL) reconstruction and knee arthroscopy.[4,7] Thus, the purpose of this study was to determine if a difference exists in BRT before and after hip arthroscopy for femoroacetabular impingement (FAI) and labral tear in comparison to age- and gender-matched controls. We

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Fig 1. Brake reaction time was measured using an RT-2S Reaction Time tester (Advanced Therapy Products, Glen Allen, VA).

hypothesized that after hip arthroscopy for FAI and labral tear, BRT would not be significantly different from preoperative values or from that of age- and gender-matched controls. Additionally, BRT was expected to correlate with STST scores.

Methods

Institutional review board approval was obtained for this prospective investigation. Adult (aged >18 years) male and female subjects undergoing primary right or left hip arthroscopy by a single surgeon were offered eligibility. Individuals with symptomatic cam and/or pincer FAI and labral tear that had failed nonsurgical treatments and undergone hip arthroscopy (labral repair, cam and/or pincer osteoplasty, capsular repair) with a minimum of 8 weeks' follow-up were included. Consecutive subjects underwent surgery between March 2015 and June 2015. Subjects with arthritis (<2 mm of joint space, Tonnis grade 2 or 3) or dysplasia (lateral center edge angle <20°, anterior center edge angle <20°, Tonnis angle >15°, femoral head extrusion index >25%) were excluded. Subjects without a valid driver's license, with neurologic disease, pain in other joints of the lower extremities, unable to complete the BRT every 2 weeks for 8 weeks, or having undergone a prior ipsilateral hip arthroscopy were excluded. Patients were assessed preoperatively (maximum of 6 weeks), and every 2 weeks (±2 days at each exact 2-week interval) postoperatively at physical therapy or physician office visits up to 8 weeks postoperatively. Age- (±3 years) and gender-matched control individuals were enrolled and tested once in the exact same protocol described above for the study subjects, recording both BRT and STST results. Control subjects were selected from employees in the orthopedic surgery department offices of the hospital in which the investigation was conducted. Subject demographics (age, gender, reason for surgery, side of surgery, date of surgery, and specific surgical procedure) were also collected.

BRT was measured using an RT-2S reaction time tester (Advanced Therapy Products; Glen Allen, VA) (Fig 1). BRT was measured by the same person every time, a study author (B.J.G., physician assistant student with Bachelor of Science degree) who was not the senior author surgeon that performed the hip arthroscopy. The RT-2S is a simple 3-piece instrument that allows the operator to control and reset each test with a remote control. The RT-2S has shown validity and reliability using a 396-individual sample of male and female healthy adults.[9] The RT-2S has revealed significant test-retest reliability (strong correlation, $r = 0.871$).[10] Subjects were seated with pedals fixed at a distance, which corresponded to the patient's usual driving position, allowing for a comfortable application of their right foot to the gas or brake pedal (Fig 2). The RT-2S display with a green and red light was placed on a table at a fixed distance from the patient. Subjects were first asked to completely depress the accelerator, which activated the green light on the display. Subjects were instructed that a red light would be appearing and to remove their foot from the accelerator and place it on the brake pedal as rapidly as possible on its recognition. Five to 30 seconds after the appearance of the green light, the red light was triggered by the investigator, and subjects applied the brake as quickly as possible. The time between the red light's appearance and the activation of the brake was displayed by the monitor and recorded as the BRT. Each subject performed 3 trials prior to completing the BRT test 10 times. The mean of the 10 BRT times was calculated for each participant. This exact procedure was performed once for the right leg and once for the left leg. The STST was also

Fig 2. Using the RT-2S Reaction Time tester, subjects were seated with pedals fixed at a distance that corresponded to the patient's usual driving position, allowing for a comfortable application of their right foot to the gas or brake pedal.

Table 1. Control and Study Subject Demographics

	Right Hip Arthroscopy (n = 11)	Controls (n = 11)	Left Hip Arthroscopy (n = 8)	Controls (n = 8)
Sex, male/female	6/5	6/5	3/5	3/5
Average age, years, mean ± SD	37.1 ± 12.7	35.5 ± 11.1	32.1 ± 9.2	32.6 ± 8.4

SD, standard deviation.

performed at the end of each session. In the STST, patients were instructed to rise from sitting as many times as possible in 10 seconds.[8] Results (number of complete repetitions) were recorded by the investigator.

Statistical analysis was performed using Social Science Statistics resources (http://www.socscistatistics.com). Means and standard deviations were calculated for continuous variables. The Mann-Whitney test was used for comparing controls and treatment groups at different time intervals. Analysis of variance was used to compare pre- and postoperative values in subjects. Spearman rho calculation was used for correlating BRT and STST scores. A P value less than .05 was defined as statistically significant. Prior to the conduct of the study, a sample size calculation determined that a minimum of 18 subjects per group were necessary to detect, with 80% power, a difference of 0.2 seconds in BRT.

Results

There were a total of 21 subjects recruited for the study. However, 2 were unable to complete the BRT testing within the required intervals of time and were excluded. The study participants included 10 women and 9 men with an average overall age of 35.0 years (±11.38). The 19 matched controls consisted of 10 women and 9 men with an average age of 34.3 years (±9.93) (Table 1). All study participants underwent hip arthroscopy, which included a labral repair, femoroplasty, acetabuloplasty, and capsular repair.

The average preoperative brake time was not significantly different between the right and left leg for both subjects in the right and in the left hip arthroscopy groups. In the right hip arthroscopy group, subjects had no difference in BRT at any time point when compared with preoperative values (Table 2). Compared with control values, there were no significant differences in BRT for the right hip arthroscopy group at any time point (Table 3). Similarly, in the left hip arthroscopy group, there was no significant difference of BRT postoperatively when compared with preoperative or control values. When grouped together (right and left), there was no significant difference in pre- and postoperative BRT at any time point. When grouped together (right and left), there was no significant difference in pre- or postoperative BRT compared with controls.

Postoperative STST scores were not significantly different from the preoperative values for either group. However, both the right and left hip arthroscopy groups showed a significant decrease at 2 weeks compared with the control group (P = .0198 and P = .0155, respectively) (Table 3). There was no other time point where STST scores were significantly different from control values. Patients had a continuous improvement of the STST during therapy. There was a strong negative correlation between BRT and STST scores in the control group and at the preoperative (r = [−]0.63), and postoperative week 4 (r = [−]0.53) and 6 (r = [−]0.53) time intervals, but not at postoperative week 2 (r = [−] 0.32; moderate negative correlation) and 8 (r = [−] 0.14; no correlation) intervals (Table 4).

Discussion

The most important finding of this study was that no significant difference in pre- and postoperative BRT was identified in patients undergoing hip arthroscopy at up to 8-week follow-up, confirming the authors' hypothesis. No significant difference in pre- or postoperative BRT was identified in comparison to age- and gender-matched controls, confirming the authors' hypothesis. Additionally, BRT correlated with STST scores at preoperative and 4- and 6-week postoperative time points, partially confirming the authors' hypothesis.

BRT has been investigated in the setting of other orthopaedic procedures, including ACL reconstruction, metatarsal osteotomy, total hip arthroplasty, and total knee arthroplasty.[2,4,6,11] In a study similar to the current investigation evaluating BRT after knee arthroscopy, Hau et al.[7] showed that BRT was significantly slower 1 week after surgery, but returned to baseline at 4 weeks postoperatively. Based on the outcome of the Hau et al. study, a significant difference may have been detected in the current study population had they been tested at 1-week intervals.

Nguyen et al.[4] evaluated 16 patients who had undergone right ACL reconstruction and found significantly slower BRT than controls until week 6. MacDonald and Owen tested 25 patients before and after total hip arthroplasty and found that the mean BRT improved significantly at 8 weeks from preoperative values.[11] Unlike these results, the current study revealed no difference in BRT between control and study groups preoperatively or postoperatively at any

Table 2. Mean Brake Reaction Time for the Right Leg and Sit-to-Stand Test Scores in Right Hip Arthroscopy, Left Hip Arthroscopy, and Their Matched Control Groups

	Brake Reaction Time, ms				Sit-to-Stand Test Score			
	Right Hip Arthroscopy	Control	Left Hip Arthroscopy	Control	Right Hip Arthroscopy	Control	Left Hip Arthroscopy	Control
Preoperative	604 ± 148	516 ± 125	598 ± 121	504 ± 63.4	6.81 ± 2.93	8.45 ± 3.11	6.25 ± 2.43	8.5 ± 2.39
2 weeks	608 ± 168	—	567 ± 143	—	5.09 ± 2.77	—	4.88 ± 2.53	—
4 weeks	566 ± 118	—	616 ± 178	—	6.8 ± 3.26	—	8 ± 2.45	—
6 weeks	559 ± 134	—	579 ± 162	—	7.64 ± 3.07	—	7.88 ± 2.42	—
8 weeks	595 ± 95.5	—	523 ± 87.8	—	7.88 ± 2.95	—	9.83 ± 2.86	—

NOTE. Values are mean ± standard deviation.

time point. Previous authors have also found reduced BRT in control subjects at progressive time intervals caused by the learning effect.[4,6] Thus, a significant difference between controls and postoperative BRT values may have been identified if control subjects returned for testing at the same intervals as the test subjects.

The return to safe driving of a motor vehicle after any surgery is clearly multifactorial. Although BRT alone probably is not sufficient to determine driving safety, it has been prioritized by the American Automobile Association as one of the most important values to determine whether a driver is permitted to drive.[9] Components of the BRT include mental processing time (the time necessary for the driver to see the stimulus to react, perceive the stimulus, decide on what response to activate), muscle activation time (the time necessary for the driver's muscles to contract, move the limb from the accelerator to the brake), and the device processing time (the time necessary for the machine to register the force applied to the brake pedal after release from the accelerator and display the task completion time). The BRT is the sum of these 3 factors. Before surgery, pain, loss of motion, and mechanical symptoms may preclude a quick BRT. After surgery, "normalization" of BRT may be different from preoperative values, as these factors are reduced or eliminated during the postoperative process, potentially improving BRT compared with that of control group individuals. BRT is also affected by gender, age, and driver awareness. Males, younger individuals, and more aware drivers have faster BRT.[9,12]

The difference between left- and right-sided surgeries is not necessarily the fact that the foot is most frequently used to depress the accelerator or brake pedal, but moreover that patients are seated, with both hips flexed approximately 90°, which will affect both hips, not just the surgical side. However, with regard to left-sided surgery in particular, Spalding et al.[13] argued that patients need no postoperative driving abstinence as long as they are strong enough to press the coupler pedal and have discontinued use of pain medication. In the current study, there was no significant increase in BRT in subjects after undergoing left or right hip arthroscopy. There was a significant reduction in STST scores at 2 weeks compared with control values but not compared with preoperative values. These results

Table 3. Comparison of Sit-to-Stand Test Scores and Brake Reaction Times Between Control and Preoperative Values at Each Time Interval Tested

	Right Arthroscopy				Left Arthroscopy			
	Brake Reaction Time, ms		Sit-to-Stand Test Score		Brake Reaction Time, ms		Sit-to-Stand Test Score	
	Mean	P*	Mean	P*	Mean	P*	Mean	P*
Control values								
Control vs pre-op	−88	.1499	1.64	.2627	−94	.1031	2.25	.0735
Control vs 2 weeks	−92	.2113	3.36	**.0198**	−63	.4295	3.62	**.0155**
Control vs 4 weeks	−50	.6241	1.65	.3628	−112	.2301	0.05	.6312
Control vs 6 weeks	−43	.5552	0.81	.7414	−75	.4965	0.62	.5961
Control vs 8 weeks	−79	.7114	0.57	.6383	−19	.5755	−1.33	.8103
Pre-op values								
Pre-op vs 2 weeks	−4	>.9999	1.72	.2005	31	.3735	1.37	.3173
Pre-op vs 4 weeks	38	.6745	0.01	.9124	−18	.5755	−1.75	.1499
Pre-op vs 6 weeks	45	.5552	−0.83	.5961	19	.7949	−1.63	.0735
Pre-op vs 8 weeks	9	.6384	−1.07	.1707	75	.3789	−3.58	.0658

NOTE. Bold items are statistically significant ($P < 0.05$).
Pre-op, preoperative.
*Mann-Whitney test.

Table 4. Correlation Between Brake Reaction Time and Sit-to-Stand Test Scores in Control Group and Study Groups at All Time Points Measured Using Spearman Rho Calculation

	r	*P*
Control	−0.7514	.0002
Preoperative	−0.6346	.0035
2 weeks	−0.3241	.1759
4 weeks	−0.5319	.0340
6 weeks	−0.5344	.0184
8 weeks	−0.1421	.6280

suggest that surgeons could recommend a safe return to unrestricted driving activity somewhere between the cessation of narcotic analgesics and the 2-week mark after this particular surgical procedure. Additionally, the time period when STST scores were significantly different from controls was also the time period when STST was not correlated to BRT, which may suggest that STST scores may not be an appropriate indicator of BRT for patients undergoing hip arthroscopy.

A literature review analyzing the BRT of nonoperative drivers in the general population with varying ages, driving simulation devices, conditions, and experience reports that BRT varies from 552 to 2,450 ms.[12] In the present study, no subject exceeded 1,088 ms at any time point. Thus, even if subjects had slower BRT after surgery, they were never above the range expected in the general population. This would further support the current study's suggestion that patients can safely return to driving after undergoing similar hip arthroscopy once they are no longer under the influence of narcotic analgesics.

Control subjects had STST and BRT test scores that were not significantly different from the preoperative scores of the test subjects, suggesting that the controls were well matched to the study subjects. Previous studies have correlated the STST to BRT in patients after knee arthroscopy and ACL repair; however, this test may not be reliable in patients undergoing hip arthroscopy.[7,14] Results of the current study showed significant correlation between BRT and STST measurements at some time intervals. However, although there was no significant difference in BRT in study subjects at 2 weeks postoperatively, there was a significant difference in STST scores compared with controls at 2 weeks postoperatively. This suggests the hip strength and motion required to maintain BRT may be overestimated by the STST. Thus, STST scores may be an overly conservative indicator of BRT for patients undergoing hip arthroscopy.

Limitations

This study is limited by a few important considerations. The study sample size was small, introducing the possibility of beta error, despite power analysis. An increase in the number of subjects enrolled would be necessary to adequately compare right- versus left-side hip arthroscopy subjects. The authors submit that logic and expectation would suspect that the right side would be more challenging than the left because the right foot is used to apply the accelerator and brake pedals. However, anecdotally, the authors had observed patients reporting not dissimilar challenges for either right- or left-sided hip arthroscopy. Patients frequently reported that one does not have to lift up the whole leg at the hip to go from accelerator to brake pedal—one simply rotates the leg inward. This formed the basis for the current power analysis numbers. The subjects underwent similar, but not the exact same, surgical procedures (labrum, FAI, capsule, articular cartilage). As long as the subjects were older than 18 years and were not arthritic or dysplastic, the subjects were eligible (influence of older age on BRT). Despite age-matching, some drivers may have had different years of experience driving a motor vehicle. Detection bias may be present in that the patients were tested in a biweekly manner. Although monitoring BRT weekly or multiple times per week may be able to better identify when BRT returns to its "new normal," it is challenging logistically to test patients in an outpatient setting unless all patients complete physical therapy at the same location or had a "take-home" BRT device. There are also other variables that may affect BRT that were not monitored in this study, including pain; analgesic dose; other medication intake; quadriceps strength; hip, knee, and ankle/foot range of motion; and proprioceptive sensation. There are also several other variables that may influence safe driving, such as hearing, visual acuity, and fatigue and other motor vehicle–related factors that may not be reflected in BRT values. In addition, the patient's weight-bearing status at the time of testing could have confounded the results, as patients were partial weight-bearing (20 pounds foot-flat weight-bearing) at weeks 2 and 4 and weight-bearing as tolerated at weeks 6 and 8. In addition, most patients after hip arthroscopy experience groin or hip pain after prolonged sitting (greater than 30 minutes). Thus, the current study did not account for this extended time interval for the arthroscopic patients or controls.

Conclusions

After hip arthroscopy for FAI and labral tear, BRT is not different from preoperative values or that of controls. In addition, BRT showed a significant correlation with STST in the first 6 weeks after surgery.

References

1. Giddins GE, Hammerton A. "Doctor, when can I drive?" A medical and legal view of the implications of advice on

driving after injury or operation. *Injury* 1996;27:495-497.
2. Holt G, Kay M, McGrory R, Kumar CS. Emergency brake response time after first metatarsal osteotomy. *J Bone Joint Surg Am* 2008;90:1660-1664.
3. Chen V, Chacko AT, Costello FV, Desrosiers N, Appleton P, Rodriguez EK. Driving after musculoskeletal injury: Addressing patient and surgeon concerns in an urban orthopaedic practice. *J Bone Joint Surg Am* 2008;90:2791-2797.
4. Nguyen T, Hau R, Bartlett J. Driving reaction time before and after anterior cruciate ligament reconstruction. *Knee Surg Sports Traumatol Arthrosc* 2000;8:226-230.
5. Egol KA, Sheikhazadeh A, Koval KJ. Braking function after complex lower extremity trauma. *J Trauma* 2008;65:1435-1438.
6. Dalury DF, Tucker KK, Kelley TC. When can I drive? Brake response times after contemporary total knee arthroplasty. *Clin Orthop Relat Res* 2011;469:82-86.
7. Hau R, Csongvay S, Bartlett J. Driving reaction time after right knee arthroscopy. *Knee Surg Sports Traumatol Arthrosc* 2000;8:89-92.
8. Bohannon RW. Sit-to-stand test for measuring performance of lower extremity muscles. *Percept Mot Skills* 1995;80:163-166.
9. Dickerson AE, Reistetter T, Parnell M, Robinson S, Stone K, Whitley K. Standardizing the RT-2S Brake Reaction Time Tester. *Phys Occup Ther Geriatr* 2008;27:96-106.
10. Brake A, Hernandez L, Mann L, Dickerson A, Reistetter T. A simple reaction time tester: test/retest reliability. Paper presented at the American Occupational Therapy Association Conference and Exposition, Orlando, FL, May 2010.
11. MacDonald W, Owen JW. The effect of hip replacement on driving reactions. *J Bone Joint Surg Br* 1988;70:202-205.
12. Young MS, Stanton NA. Back to the future: brake reaction times for manual and automated vehicles. *Ergonomics* 2007;50:46-58.
13. Spalding TJ, Kiss J, Kyberd P, Turner-Smith A, Simpson AH. Driver reaction times after total knee replacement. *J Bone Joint Surg Br* 1994;76:754-756.
14. Gotlin RS, Sherman AL, Sierra N, Kelly M, Scott WN. Measurement of brake response time after right anterior cruciate ligament reconstruction. *Arthroscopy* 2000;16:151-155.