

Vibratory sense deficits in patients with symptomatic femoroacetabular impingement

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Abstract

Objective: Sensory deficits, measured through vibratory perception threshold (VPT), have been recognized in hip and knee osteoarthritis (OA), but have not been evaluated in femoroacetabular impingement (FAI), thought to be a pre-OA condition. This study aimed to assess VPT in symptomatic FAI pre- and 6-months post-arthroscopy vs. controls. **Methods:** FAI patients and controls were assessed for VPT at the first metatarsophalangeal joint. Pain was assessed using a visual analog pain scale. FAI participants were evaluated again 6-months after surgery for FAI. Differences between groups and pre- and post- surgery were evaluated with independent and paired sample t-tests, respectively. Secondary analysis was performed using repeated-measures ANOVA to evaluate the effect of pain and time since surgery on VPT pre- and post-operatively. **Results:** No differences in age and BMI were seen between groups ($p>0.05$). Reduced VPT (higher value is worse) was evident in the pre- ($8.0\pm 3.9V$, $t=2.81$, $p=0.009$) and post-operative ($6.8\pm 2.8V$, $t=2.34$, $p=0.027$) patients compared to controls ($4.7\pm 1.3V$). After hip arthroscopy, there was a trend toward improved VPT ($t=1.97$, $p=0.068$). Preoperative and 6-months postoperative pain and time since surgery were not found to influence VPT ($F\text{-ratio}\geq 0.00$, $p\geq 0.427$). **Conclusion:** Sensory deficits were observed in FAI patients both before and 6-months after hip arthroscopy.

Keywords: Femoroacetabular Impingement, Sensory Deficits, Hip, Arthroscopy, Orthopedics

Highlights

- Femoroacetabular impingement (FAI), a morphological deformity of the hip joint, is thought to be a precursor to osteoarthritis (OA) of the hip; therefore, by studying FAI we can potentially understand early features of OA with individuals thought to be at risk or in the early stages of the disease.
- Sensory function, assessed through vibratory perception threshold, has been found to be altered in knee and hip OA, however it has not been examined in FAI.
- The hypothesized deficits in vibratory sense were confirmed in FAI patients before surgery and persisted 6 months after surgery.

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Introduction

Femoroacetabular impingement (FAI) is a common cause of hip pain in young patients in which chondrolabral injuries resulting from abnormal morphological alterations in the proximal femur and/or acetabulum may contribute to the development of osteoarthritis (OA)^{1,2}. FAI can be characterized by a cam or pincer deformity, with the majority of patients presenting a combination of these morphologies¹. A cam deformity describes an aspherical femoral head-neck junction and is measured by the alpha angle (AA)³, while the pincer deformity characterizes acetabular overcoverage of the hip and is assessed by the lateral center edge angle (CEA) of Wiberg⁴. FAI has a high radiographic prevalence in asymptomatic patients, but for poorly understood reasons a subset of these patients will develop hip pain that limits activities⁵⁻⁷. Following unsuccessful non-operative treatment for symptomatic FAI, hip arthroscopy offers high rates of pain relief and improvement of outcome scores⁸⁻¹⁰. Surgery aims to improve pain and restore function by reestablishing normal anatomy, and theoretically preventing further chondrolabral injury and subsequent development of OA^{1,2}.

Proprioception is involved in joint position and movement and is critical for muscular control. There are unmyelinated nerve

	Preop FAI	Postop FAI	Control
Number of subjects	16	15	12
Age (y)	28.4 ± 9.6	28.7 ± 9.6	28.2 ± 5.7
Sex (m:f)	4:12	3:12	5:7
BMI (kg/m ²)	23.5 ± 4.9	23.5 ± 5.5	22.8 ± 3.1
VPT Test Time Point (days) ^a	11.9 ± 9.6	195.3 ± 26.5	N/A
Alpha Angle (°) (Range)	63.4 ± 5.8 ^d (56.8 - 79.6)	38.6 ± 4.0 ^{d,e} (26.1 - 43.7)	52.6 ± 3.3 (47.5 - 58.4)
Center Edge Angle (°) (Range)	32.4 ± 5.1 (23.0 - 39.8)	31.0 ± 5.5 (22.3 - 38.4)	31.4 ± 6.1 (17.7 - 41.9)
VAS (mm) ^b	33.7 ± 27.3 ^d	8.8 ± 11.7 ^{d,e}	0.0 ± 0.0
HOS-ADL (%) ^c	68.0 ± 14.8 ^d	90.6 ± 7.7 ^{d,e}	100.0 ± 0.0
HOS-SS (%) ^c	49.3 ± 17.8 ^d	80.9 ± 12.9 ^{d,e}	100.0 ± 0.0
^a Number of days before or after surgery when the test was performed			
^b Visual Analog Scale of affected hip and randomly selected hip for the control group			
^c Hip Outcome Score-Activities of Daily Living and Hip Outcome Score-Sports Subscale			
^d Significantly different than control ($p < 0.001$)			
^e Significantly different than preoperative measure ($p \leq 0.015$)			

Table 1. Participant characteristics and morphological data (mean ± SD).

endings, corpuscles, and mechanoreceptors in the hip joint labrum, which may play a large role in proprioception and pain with FAI¹¹. Damage to mechanoreceptors can lead to inadequate signal propagation, resulting in abnormal motion and additional joint damage¹². In knee OA, proprioceptive deficits have been identified and have been associated with altered mechanical loading and disease state¹³. Abnormal mechanical loading attributed to muscular limitations while walking have been suggested in FAI^{14,15}. This loading pattern may potentially lead to proprioceptive deficits, or, conversely, preexisting deficits may lead to abnormal loading.

Proprioception and vibratory sensory have been shown to travel along a parallel pathway to the CNS and input for both modalities are provided through the same peripheral sensory receptors^{13,16}. Vibratory sense is assessed through vibratory perception threshold (VPT). VPT can be administered at multiple joints for sensory testing and has been shown to be more reliable than proprioceptive testing techniques which have been criticized for poor reliability, excessive variability, and confounding factors such as patient memory and pain¹³. Similar to proprioception, vibratory sense has also been shown to decrease with OA; where patients with hip OA have exhibited sensory deficits in both the upper and lower extremities^{16,17}. Alternatively, alterations in vibratory sense were not confirmed in patients at high risk or in an early phase of OA¹⁸. Similarly, such alterations have not been examined in symptomatic FAI and, if present, it is not clear whether these deficits are altered following hip arthroscopic intervention in this group.

We investigated whether sensory deficits are present in FAI and if they are improved following arthroscopic surgery. We

hypothesized that there would be significant sensory differences between both pre- and post-operative FAI patients compared to a control group and that sensory deficits would improve at 6-months follow-up after hip arthroscopic surgery.

Material and methods

Patient population: Sixteen FAI patients and 12 age-matched controls participated in this study with 15 patients returning for a 6-month postoperative follow-up (Table 1). This study was approved by the Institutional Review Board and informed consent was obtained prior to participation. Patients with the following criteria were enrolled: 1) clinical and radiographic evidence (AA $\geq 50^\circ$ and/or CEA $\geq 20^\circ$) of FAI and failure of non-operative management; 2) pain during a positive hip flexion, adduction, and internal rotation maneuver (impingement test) on physical exam; 3) those scheduled to undergo hip arthroscopic surgery, including labral repair and acetabular and/or femoral osteochondroplasty, for the FAI; and 4) those with a Kellgren-Lawrence (KL) grading scale of ≤ 1 on pelvic radiographs. Exclusion criteria included presence of hip dysplasia (CEA $< 20^\circ$); prior surgery on the cognate joint; radiographic signs of osteoarthritis (KL > 1); and/or lumbar/lower extremity pathologies. Patients returned to the host institution to complete a 6-month postoperative evaluation as part of the operating surgeon's standard of care.

Control subjects were recruited from the surrounding community. Inclusion criteria for these participants were: 1) no known history of lumbar/lower extremity pathology or surgery, 2) no pain or movement dysfunction, 3) absence of symptomatic FAI (as previously described above) even in the presence of FAI

pathoanatomy, 4) absence of radiographic hip OA. Individuals in both groups were excluded if they were pregnant or suspected pregnancy or if they had diabetes and/or peripheral neurovascular disease or damage.

Radiography: Radiographic analysis was performed by a single orthopedic surgeon for both groups. All patients underwent pre- and post-operative standard pelvic radiographs with anteroposterior, false profile, and oblique lateral (Dunn) views. All radiographs were performed with the patient in a supine position and the coccyx positioned midline, approximately one centimeter above the pubic synthesis (neutral tilt) and the obturator foramina and the trochanters symmetric (neutral rotation)¹⁴. The AA was measured by a line from the center of the femoral head that bisects the femoral neck and the line from the center of the femoral head to the point where the femoral head loses sphericity. The largest measured AA was selected at the cam deformity as it may be more prominent on varying views depending on its location. The CEA is measured by the vertical line from the center of the femoral head and the line from the center of the femoral head to the superolateral aspect of the acetabulum¹. Both parameters were measured on digital radiographs using a digital picture archiving and communication system.

Vibratory perception threshold: Vibratory sense is measured through VPT in volts (V). VPT was assessed using a biothesiometer (Bio-Medical Instrument, Newberry, OH) according to previously published methods¹⁶. Biothesiometry has been shown to have high reproducibility and reliability as a means to assess VPT (9). The biothesiometer has a small vibrating tip that oscillates at constant frequency of 120 Hz. The first metatarsophalangeal (MTP) joint on the patient's affected side was used as the site of application for the FAI participants and a randomly selected limb for the control participants. The MTP site was chosen because the largest difference was seen between patients with hip OA and control subjects at this site in previous work¹⁶.

Patients were instructed to lie in supine position with their foot in a neutral, relaxed position (not dorsiflexed or plantar flexed) and instructed not to move. The tip of the biothesiometer was applied against the skin with the consistent pressure by using the weight of the testing device with the applicator being held at its proximal end at the site of attachment to the power cord. They were given a demonstration of the biothesiometer on their hand prior to testing on the first MTP with the voltage examples of zero, moderate, and high. The same demonstration was then performed at first MTP on the affected side. The official test was then performed with a voltage rate of 1 V/s starting at 0 V. Upon first sensation of the vibration, patients were instructed to comment and this was noted as the VPT. The VPT measurement was obtained with three trials (later averaged) with the tip of the biothesiometer remaining on the surface of the skin to ensure testing reliability. A VPT value of higher magnitude signifies a greater sensory deficit. The same two investigators performed the test: one was responsible for applying the applicator while the other operated the dial.

Self-reported outcomes: As part of the orthopedic surgeon's standard of care, individuals from both groups completed a visual analog scale (VAS) measuring pain on the affected hip for the FAI patients and the randomly selected hip from the control

	Preop FAI	Postop FAI	Controls
VPT	8.0 ± 3.9 ^a (3.5 - 19.2)	6.8 ± 2.8 ^{a,b} (2.7 - 13.0)	4.7 ± 1.3 (3.2 - 7.3)
^a Significantly higher than the control group ($p \leq 0.027$) ^b Trend toward improved postoperative VPT compared to preoperative ($p = 0.068$)			

Table 2. Vibration Perception Thresholds (VPT) in pre- and post-operative FAI patients and control subjects (mean ± SD and range).

group¹⁹. The Hip Outcome Score Activity of Daily Living (HOS-ADL) and Sports-Specific Subscales (HOS-SS), which evaluated hip-specific functional outcome scores, were also completed¹³.

Statistical analysis: Analysis was performed using IBM SPSS Statistics 22 (PASW 22, SPSS Inc., IBM, Armonk, NY). Independent t-tests were used to determine significant differences between both pre- and post-operative FAI patients and the control group. Paired t-tests were used to assess pre- and post-operative differences within the FAI group. Secondary analysis was performed using repeated measures ANOVA to evaluate the effects of pain on pre- and 6-month post-operative VPT. Power analysis assuming large differences between means (effect size $d = 0.5$), to achieve 95% power showed that a sample size of 17 per group satisfies requirements²¹. The level of significance for this two-tailed test was set at $\alpha < 0.05$.

Results

Demographic and morphological data is presented in Table 1. The VPT was significantly higher in the preoperative FAI patients compared to the control group ($t = 2.81$, $p = 0.009$) as well as in the postoperative FAI patients compared to the controls ($t = 2.34$, $p = 0.027$). There was a trend toward improved VPT in FAI patients following hip arthroscopy ($t = 1.97$, $p = 0.068$) (Table 2).

Following surgery, patients' scores significantly improved with respect to pain ($t > 3.35$, $p \leq 0.005$), as well as the HOS-ADL ($t \leq -7.83$, $p < 0.0001$) and HOS-SS ($t \leq -6.53$, $p < 0.0001$) subscales (Table 1).

Secondary analysis using repeated measures ANOVA showed that pain, (pre: F-ratio=0.000, $p = 0.987$; post: F-ratio=0.652, $p = 0.427$) and time since surgery (pre: F-ratio=1.242, $p = 0.285$; post: F-ratio=2.134, $p = 0.168$) were not determining factors for pre- and post-operative VPT.

Discussion

To the best of the authors' knowledge, this study was the first to evaluate vibratory sense in patients with symptomatic FAI. We observed significant impairment of preoperative vibratory sense as measured by VPT in FAI patients compared to controls. This confirmed our first hypothesis. Following hip arthroscopy, FAI patients had significant improvements of AA, outcome scores,

and pain; however, postoperative VPT remained significantly lower than controls. Our second hypothesis that an improvement in VPT following arthroscopic surgery was not confirmed, but there was a trend toward improvement.

The presence of impaired vibratory sense in FAI patients relative to the controls suggests a lower extremity sensory deficit in FAI. Vibratory sense deficits have previously been identified in patients with hip OA¹⁶. Shakoor et al.¹⁶ reported a significantly greater mean VPT of 13.5 ± 1.4 V in 14 subjects with hip OA compared to 7.4 ± 0.7 V for an age-matched control group of 13 subjects. The higher VPT for patients in the Shakoor et al.¹⁶ study than the present study is likely a result of the fact that vibratory sense decreases with age and our study evaluated the much younger FAI population (64 ± 10 y vs. 29 ± 10 y)^{16,18}. The presence of vibratory sensory deficits in both FAI patients and hip OA patients is intriguing given the potential role of FAI in OA pathogenesis via chondrolabral injury^{22,23}. We are unable to determine whether the impaired sensory perception observed in FAI is a primary deficit contributing to FAI and/or hip OA pathogenesis or secondary to FAI itself (e.g. via damage to hip joint sensory receptors). Pain as measured by VAS was found not to be associated with VPT in our study and has not been associated with VPT in a previous study¹³ suggesting that FAI patients have a sensory deficit independent of pain. Whether primary or secondary, impaired vibratory sensation in FAI patients could theoretically play a role in hip OA development if impaired sensation led to increased propensity for mechanically induced chondrolabral damage. Future research to address these questions will be essential to elucidate the role of vibratory sense deficits in FAI and hip OA pathogenesis.

The trend toward improved vibratory sense following hip arthroscopy for symptomatic FAI suggests that surgical intervention may improve the observed preoperative sensory deficits. Hip and knee arthroplasty studies have shown that surgery can improve sensory function. Attfield et al.²⁴ demonstrated improvements in postoperative proprioception while in both a flexed and extended position following a total knee replacement 3- and 6-months postoperatively²⁴. Moreover, improvements in joint perception were noted in 20 patients 40 days following total hip arthroplasty (THA) in a study by Zati et al.²⁵. The reasons for lack of significant improvement following hip arthroscopy and the continued significant postoperative impairments relative to controls are not clear. One possibility is a type II error, in which our sample size yielded insufficient power to detect a truly significant difference. Alternatively, sensory perception might continue to improve beyond the 6-month time point following surgery at which we obtained postoperative VPT measurements. Lastly, sensory deficits might represent a more fundamental abnormality in patients that predisposes them to FAI, but is not affected by surgery. Future study is needed to clarify these questions.

This study is not without limitations. First, the sample size was small, but despite the size, significant relationships were still observed. Second, afferent deficits were only evaluated at the first MTP and systematic sensory effects could not be accounted. Previous research, however, demonstrated significant differences at multiple testing sites suggesting assessments could occur at a single site¹⁶. Third, the majority (70%) of the controls

included in this study presented with FAI morphology but did not complain to pain, and therefore, these patients did not meet the clinical diagnosis of FAI. Fourteen to 35% of the population present as asymptomatic FAI²⁶ and elevated AA and CEA are commonly seen in asymptomatic individuals that who do not present with hip pain^{5,27}. Furthermore, the significant relationship between the group's AA and not the CEA is not uncommon as symptomatic FAI patients are more likely to present with at least a cam deformity rather than individuals who are FAI pathoanatomy free²⁶. Nonetheless, including those with asymptomatic FAI would have only biased our results toward the null, so the fact that we were able to still observe significant differences between the symptomatic FAI group and controls is compelling. Finally, this study is not able to determine the cause for vibratory sense deficits. Although pain was considered as a covariate, there may be other differences. For example, physical activity or other anatomic factors may affect sensation. These questions should be explored in future pathophysiological studies.

Vibratory deficits have been previously observed in those with knee and hip OA. The results shown here may have significant implications in our understanding of FAI pathophysiology and suggest that sensory alterations independent of pain may be present early in the disease process and are potentially improved following arthroscopic surgery for FAI. Further research, including a larger cohort and longer term follow-up may help determine if these alterations are reversible with intervention and how they may relate with disease progression over time.

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