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Austin Looney

Hannah Day

Manoj Reddy

Ryan Paul

Levon Nazarian

See next page for additional authors

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Authors
Austin Looney, Hannah Day, Manoj Reddy, Ryan Paul, Levon Nazarian, and Steven Cohen

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Original Research

Physical Examination Versus Ultrasonography for Detection of Ulnar Nerve Subluxation in Professional Baseball Pitchers

Austin M. Looney,[¶†] MD, Hannah K. Day,[‡] MD, Manoj P. Reddy,[¶§] MD, Ryan W. Paul,[¶] BS, Levon N. Nazarian,[||] MD, and Steven B. Cohen,[*¶] MD
Investigation performed at The Rothman Orthopaedic Institute, Philadelphia, Pennsylvania, USA

Background: Despite the importance of accurately detecting ulnar nerve subluxation in vulnerable athletes, few studies have compared the performance of physical examination and ultrasound in this population.

Purpose/Hypothesis: The purpose of this study was to compare the diagnostic validity of physical examination versus ultrasound in detecting ulnar nerve subluxation at the cubital tunnel of the elbow in professional baseball pitchers. It was hypothesized that ultrasound would more sensitively detect ulnar nerve subluxation.

Study Design: Cohort study (diagnosis); Level of evidence, 2.

Methods: Physical and sonographic examinations for ulnar nerve subluxation were performed on 186 elbows of 95 consecutive male professional baseball pitchers (age, 17-30 years) as a routine part of their spring training assessments. Provocative maneuvers consisting of the Tinel and elbow flexion-compression tests were evaluated over the cubital tunnel. The validity of physical examination for detecting ulnar nerve subluxation at the elbow was determined using ultrasonographic examination for comparison.

Results: Ulnar nerve subluxation was detected by physical examination in 58 (31.2%) elbows and by ultrasonography in 61 (32.8%) elbows. Of the 58 elbows with positive physical examination, 47 were positive on ultrasound. Using a positive ultrasound as a reference, the accuracy of the physical examination was 86.6%, with 77% sensitivity and 91.2% specificity. The positive and negative predictive values of physical examination were 81% and 89.1%, respectively. There was no relationship between nerve instability and positive provocative tests overall, in dominant versus nondominant arms, or in right versus left arms ($P > .05$ for all).

Conclusion: Physical examination had moderate sensitivity and high specificity for detecting ulnar nerve subluxation at the cubital tunnel of the elbow when compared with ultrasound. These findings suggest that when detecting the presence of a subluxating ulnar nerve is most important, it may be advisable to obtain an ultrasound evaluation instead of relying on a physical examination; however, physical examination alone may be appropriate for ruling out subluxation.

Keywords: baseball; physical examination; pitchers; ultrasound; ulnar nerve; subluxation

The incidence of asymptomatic ulnar nerve instability in the general population has been reported[1] as high as 37%. While this condition may be inconsequential for many, a subluxating ulnar nerve in those who regularly perform activities involving repetitive, forceful elbow extension can be associated with pathologic symptoms. In 1975, Childress[3] outlined the particular vulnerability of the subluxated position as the nerve is tensioned along the prominent medial border of the medial epicondyle. The repetitive, forceful flexion-extension demands of baseball place a subluxating ulnar nerve frequently in a position vulnerable to tractional and frictional injury.[1] A study[18] of 246 male college athletes showed a significantly higher frequency of ulnar nerves in the subluxated or dislocated position in baseball and rugby players versus soccer players and cross-country runners ($P < .001$). Furthermore, the baseball and rugby group also demonstrated a significantly higher frequency of ulnar nerve pushout by the triceps long head from the cubital tunnel compared with the soccer players and runners ($P < .001$).

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Ulnar neuropathy in baseball players can be a poor prognostic factor of return to play and may complicate the results of ulnar collateral ligament (UCL) reconstruction (UCLR).[8,13] Baseball pitchers undergoing UCLR have been observed[6] to be 10% less likely to return to sports when preoperative ulnar neuritis was present compared with pitchers without preoperative neuritis (82% vs 92%; P = .04). Accurate detection of ulnar nerve instability—when correlated with a history of ulnar neuritis symptoms and/or positive provocative testing—is paramount in identifying athletes at risk for career-compromising injuries. Failure to address symptomatic ulnar nerve instability in these athletes has the potential to result in suboptimal outcomes, including the substantial odds of a permanent inability to return to play, and a diagnosis in symptomatic athletes may offer important prognostic information to both players and organizations.

Historically, ulnar nerve subluxation has been diagnosed through physical examination utilizing palpation with extension of the elbow from flexion to a neutral supine position.[1,2] Because of improvements in imaging quality and diagnostic accuracy, superficial access to the ulnar nerve, and an increased understanding of the impact of ulnar nerve pathology, dynamic ultrasound has become an increasingly utilized modality for the evaluation of ulnar neuritis and, more recently, for identifying ulnar nerve subluxation.[5,10,12,18,19] The only previous study evaluating ulnar nerve subluxation with ultrasound, specifically in baseball players, focused on youth athletes and found that 44% of dominant elbows and 19% of nondominant elbows experienced ulnar nerve instability.[12]

Despite the importance of accurately detecting the presence of ulnar nerve subluxation in vulnerable athletes, minimal research has compared the performance of physical examination and ultrasound in this population. The primary purpose of this study was to characterize the diagnostic validity of physical examination in detecting ulnar nerve subluxation at the cubital tunnel of the elbow compared with ultrasound. We hypothesized that ultrasound would more sensitively detect ulnar nerve subluxation when compared with physical examination.

METHODS

Patients

With institutional review board approval and in cooperation with a single Major League Baseball (MLB) organization, data were collected during routine spring training entrance physical examinations for consecutive professional baseball pitchers. All athletes in the present study were pitchers in the minor league system affiliated with an MLB team, and all gave written informed consent. A brief history was obtained before conducting the examinations. Elbows in which ulnar nerve release/decompression/transposition had been performed were excluded; however, the contralateral elbow was examined. Elbows with a history of UCL surgery were not excluded a priori to maximize the inclusion of consecutive athletes. These athletes did not have symptoms of ulnar neuritis or symptomatic subluxation before surgery; thus, UCL surgery was performed in isolation. Athletes were also questioned about symptoms of ulnar neuritis/neuropathy. Patients with ongoing or history of ulnar nerve symptoms were not excluded if no formal treatment had been performed. Patients remained blinded to the physical examination and ultrasound findings until the conclusion of testing.

Physical Examination

All athletes underwent a physical examination before any ultrasound imaging was obtained. Physical examinations were performed by the same author (A.M.L.)—an orthopaedic surgery sports medicine fellow who was unaware of upper extremity dominance at the time of screening. Subluxation testing was performed as described by Calfee et al,[2] with both "perching" and "dislocating" nerves considered positive for subluxation. The Tinel test[17] and the elbow flexion-compression test[16] were assessed at the cubital tunnel by the same author and performed and interpreted as previously described in detail.[2] Briefly, this involved visual inspection for gross instability during flexion and extension of the elbow, as well as systematic palpation at different degrees of flexion to assess the location of the ulnar nerve and determine its degree of stability or mobility in relation to multiple landmarks—including the posteromedial aspect of the medial humeral epicondyle and the cubital tunnel. The systematic steps were also repeated as necessary to differentiate between the ulnar nerve, synovium, triceps, and subcutaneous tissue.

Ultrasound Assessment

Sonographic assessments were performed on a Sonosite PX ultrasound system (Fujifilm) with a 15-MHz linear

*Address correspondence to Steven B. Cohen, MD, The Rothman Orthopaedic Institute, 925 Chestnut Street, 5th Floor, Philadelphia, PA 19107, USA (email: Steven.Cohen@rothmanortho.com).
†Guilford Orthopaedics and Sports Medicine, Greensboro, North Carolina, USA.
‡University of California–Davis Medical Center, Sacramento, California, USA.
§Baylor Scott & White Orthopedic Associates of Dallas, Dallas, Texas, USA.
||Department of Radiology, Thomas Jefferson University Hospital, Philadelphia, Pennsylvania, USA.
¶Sports Medicine Division, The Rothman Orthopaedic Institute, Philadelphia, Pennsylvania, USA.
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Ethical approval for this study was obtained from Philadelphia University–Thomas Jefferson University (no. 21D.056).

transducer by a different author (L.N.N.) according to the technique described by Endo et al.[7] This author is a board-certified radiologist, fellowship trained in musculoskeletal imaging, and routinely uses ultrasound in practice. He was blinded to the results of the physical examination and the athletes' histories regarding specific symptoms and was unaware of arm dominance at the time of screening. However, he was aware of previous surgeries because these were evaluated as part of the routine protocol (eg, assessing graft integrity in UCLR case). The technique of Endo et al[7] involves the examiner facing the patient's medial elbow, with the patient's shoulder flexed slightly and the elbow starting in full flexion. The ultrasound probe is placed with medium pressure at the medial epicondyle to obtain a cross-sectional view of the ulnar nerve. As the elbow is passively extended at least 90° from the position of full flexion, the nerve is observed to have no subluxation (type N), subluxation (type S), or dislocation (type D), based on its position in relation to the tip of the medial epicondyle (anteromedial, on top of, fully crossed over, respectively). In this study, nerves that were type S (subluxation) and type D (dislocation) were considered positive for subluxation.

Statistical Analysis

Categorical variables were described in terms of counts and percentages. Continuous variables were reported as mean and standard deviation if normally distributed and median with interquartile range if nonparametric. Continuous variables were tested for normality using the Shapiro-Wilk test. Categorical variables were compared with the Fisher exact test. Comparisons between continuous variables were performed with the Student *t* test if normally distributed and the Mann-Whitney *U* test if nonparametric. We used ultrasonographic evaluation as the comparative diagnostic modality to physical examination. The overall accuracy of the physical examination was calculated (95% CI), and agreement was quantified with the Cohen κ, in which κ values were interpreted as follows: 0 to 0.20, no agreement; 0.21 to 0.39, minimal; 0.40 to 0.59, weak; 0.60 to 0.79, moderate; 0.80 to 0.90, strong; and >0.90, almost perfect agreement.[14] Epidemiologic parameters were estimated, including sensitivity, specificity, positive predictive value, and negative predictive value. Significance was defined as $P < .05$. All analyses were conducted in the R statistical environment (R Version 4.0.4, "Lost Library Book", The R Foundation for Statistical Computing).

RESULTS

A total of 186 elbows (91 in the dominant arm, 95 in the nondominant arm) in 95 MLB pitchers were examined. Four elbows were not analyzed because of a history of ulnar nerve transposition. Also, 17 athletes had a history of UCL surgery (without ulnar nerve transposition; 16 reconstructions, 1 repair). With few exceptions, the reconstructions were performed on the dominant arm. There was no association between isolated UCL surgery and subluxation on physical examination (5 positive, 9 negative; P = .761) or ultrasound (6 positive, 8 negative; P = .552). The excluded elbows were all in the dominant throwing arm; all were right elbows. No athletes reported experiencing ulnar neuritis/neuropathy symptoms. The selection process is outlined in Figure 1. Characteristics of the included athletes are summarized in Table 1.

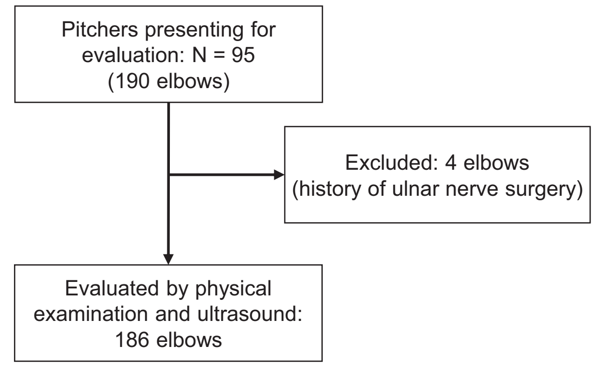

Figure 1. Patient-selection process.

TABLE 1
Baseline Characteristics of the Study Sample (N = 95 MLB Pitchers)[a]

Characteristic	Value
Age, y	22 [21-24]
Range	17-30
Arm dominance, left/right	28 (29.5)/67 (70.5)
Height, cm	191 [185-193]
Range	178-208
Weight, kg	95.4 ± 2.4
Range	66-129
BMI, kg/m^2	26.5 ± 0.7
Range	18.6-33.8
Professional experience, y[b]	2 [0-3]
Range	0-6

[a]Data are presented as median [interquartile range], mean ± 2SD, or n (%) unless otherwise indicated. BMI, body mass index; MLB, Major League Baseball.
[b]Calculated as n − 1 of number of spring trainings attended.

Subluxation was detected on ultrasound in 61 (32.8%) elbows—including 32 (35.2%) in the dominant arm and 29 (30.5%) in the nondominant arm. The prevalence of bilateral ulnar nerve subluxation was 26.4% (95% CI, 17.7%-36.7%), occurring in 24 out of the 91 athletes. Ulnar nerve subluxation was detected by physical examination in 58 (31.2%) elbows, including 29 (31.9%) in the dominant arm and 29 (30.5%) in the nondominant arm. Of the 58 elbows with positive physical examination, 47 were positive on ultrasound. There was a moderate agreement between physical examination and ultrasound (κ = 0.69; P = .689). Physical examination accuracy was 86.6% (95% CI, 80.8%-91.1%), with 77% sensitivity (95% CI, 64.5%-

TABLE 2
Performance of Physical Examination Versus Ultrasonography[a]

Parameter	Estimate (95% CI)
Accuracy	86.6 (80.8-91.1)
Sensitivity	77 (64.5-86.8)
Specificity	91.2 (84.8-95.5)
PPV	81 (68.6-90.1)
NPV	89.1 (82.3-93.9)
PLR	8.76 (4.90-15.65)
NLR	0.25 (0.16-0.40)
DOR	34.79 (14.73-82.19
NND	1.47 (1.21-2.03)
Youden index	0.68 (0.49-0.82)

[a]Data are presented as % (range) unless otherwise indicated. DOR, diagnostic odds ratio; NND, number needed to diagnose; NLR, negative likelihood ratio; NPV, negative predictive value; PLR, positive likelihood ratio; PPV, positive predictive value.

86.8%) and 91.2% specificity (95% CI, 84.8%-95.5%). The positive predictive value was 81% (95% CI, 68.6%-90.1%), and the negative predictive value was 89.1% (95% CI, 82.3%-93.9%). Additional performance parameters are presented in Table 2.

The Tinel test over the cubital tunnel was positive in 9 (4.8%) elbows—including 4 (4.4%) in the dominant arm and 5 (5.3%) in the nondominant arm. The cubital tunnel flexion-compression test was positive in 3 elbows (1.6%)—including 1 (1.1%) in the dominant arm and 2 (2.1%) in the nondominant arm. Of the 61 elbows with ultrasound-positive subluxation, 1 (1.6%) had a positive Tinel test, and 1 (1.6%) had a positive flexion compression test. There was no relationship between ulnar nerve subluxation and positive provocative tests overall, in dominant versus nondominant arms, or in right versus left arms (Table 3).

TABLE 3
Comparison Between Positive Provocative Tests on Physical Examination and Ulnar Nerve Subluxation on Ultrasound Overall by Arm Dominance and by Side[a]

	Positive Tinel Test	Positive Flexion-Compression Test
Overall		
Stable (n = 125)	8 (6.4)	2 (1.6)
Subluxating (n = 61)	1 (1.6)	1 (1.6)
P	0.275	>.999
Dominant arm		
Stable (n = 59)	4 (6.8)	1 (1.7)
Subluxating (n = 32)	0 (0)	0 (0)
P	0.293	>.999
Nondominant arm		
Stable (n = 66)	4 (6.1)	1 (1.5)
Subluxating (n = 29)	1 (3.4)	1 (3.4)
P	> .999	0.52
Right arm		
Stable (n = 62)	4 (6.5)	1 (1.6)
Subluxating (n = 29)	0 (0)	0 (0)
P	0.302	> .999
Left arm		
Stable (n = 63)	4 (6.3)	1 (1.6)
Subluxating (n = 32)	1 (3.1)	1 (3.2)
P	0.66	> .999

[a]Data are reported as No. of elbows (%).

DISCUSSION

The main finding of this investigation was that physical examination had moderate sensitivity (77.1%) and high specificity (91.2%), with moderate agreement (κ = 0.69), for detecting ulnar nerve subluxation at the cubital tunnel in this population of athletes compared with ultrasonography. Only 1 athlete with an ultrasound-positive subluxating ulnar nerve had positive Tinel and cubital tunnel flexion compression tests. All other positive Tinel and flexion compression tests occurred in arms in which ultrasonography did not find evidence of ulnar nerve subluxation. Furthermore, none of the tested athletes reported any limitations from or concerns related to ulnar nerve symptoms. These findings indicate that in this population of professional athletes, a subluxating ulnar nerve detected by ultrasound or physical examination is not predictive of symptomatic or function-impairing ulnar nerve instability. This is evidenced by the lack of association between positive provocative testing and sonographic ulnar nerve instability, as well as a 0% reported prevalence of pain, neuropathy, or impact on play or performance among athletes both with and without observed ulnar nerve instability.

This is the first study characterizing the accuracy and validity of physical examination using ultrasound as a reference in detecting ulnar nerve subluxation at the elbow. Calfee et al[2] examined 400 elbows in 200 patients to determine the interobserver reliability of physical examination for ulnar nerve hypermobility at the cubital tunnel. They observed ulnar nerve instability in 148 (37%) of the 400 elbows they examined, with a high percentage of agreement (88%) between the 3 examiners. Interobserver reliability was slightly higher (κ = 0.72 on the right, κ = 0.74 on the left) than the reliability between examination and ultrasound (κ = 0.69). Agreement statistics were not significantly improved when only the results of 2 senior examiners were analyzed. Calfee et al[2] also reported a pattern of increased positive provocative cubital tunnel tests (Tinel, flexion compression) among patients with hypermobile ulnar nerves. However, this was statistically significant only for the Tinel test in left elbows (*P* = .04). By contrast, we did not observe any apparent relationship between ulnar nerve subluxation and positive provocative tests.

Van Den Berg et al[19] utilized ultrasound to study the ulnar nerves of 342 patients with ulnar neuropathy at the elbow in addition to a cohort of 70 healthy controls. They observed ulnar nerve subluxation in 8 (11%) of the asymptomatic control patients and 70 (21%) of the patients with symptomatic ulnar neuropathy. The difference between groups was not significant (P = .12). They did not evaluate nerve stability with examination. These figures are much lower than the prevalence detected by ultrasound in the present study (31.2%), which may be related to demographic differences in the study populations. All participants in our study were male professional athletes aged 17 to 30 years. By contrast, the healthy controls in the study by Van Den Berg et al[19] included 28 men and 42 women, with a mean (±SD) age of 42.8 ± 14.5 years (range, 19-79 years), and the symptomatic cohort included 167 men and 175 women, with a mean (±SD) age of 48.8 ± 14.4 years (range, 13-86 years).

The prevalence of subluxation detected by ultrasound in this study was more similar to the findings of more recent studies.[5,7] As part of a wellness and health screening program, Endo et al[7] obtained ultrasound evaluations of 306 elbows in 153 healthy controls (44 men, 112 women; mean age, 65.4 years) with no history of ulnar nerve pathology. Ulnar nerve subluxation was observed in 131 (42.8%) of all elbows. Cornelson et al[5] performed ultrasound assessments of 84 elbows in 42 healthy asymptomatic patients (25 men, 17 women; mean age, 26.7 years [range, 22-40 years]), including several athletes. They detected ulnar nerve subluxation in 47 (56%) of elbows and posited that the inclusion of athletes among their patients may have contributed to a higher prevalence in their sample. This hypothesis is supported by recent literature.[18]

Such a phenomenon may be related to a hypertrophic triceps in a more athletic population predisposing to ulnar nerve instability.[4,15] The medial aspect of the distal triceps can glide or snap over the medial epicondyle, known as snapping triceps syndrome.[4,11,15] This can occur in isolation but may also contribute to ulnar nerve instability.[15] Ultrasound has the added benefit over physical examination in distinguishing between a snapping triceps and a subluxating ulnar nerve.[4,9] Formal evaluation of the triceps at the elbow was not a part of the protocol in the present study. Still, it is possible that some of the false-positive cases (ie, subluxation reported on examination but not detected by ultrasound) may have been related to a snapping triceps.

Limitations

This study had several limitations. To begin with, all patients were men, and all were professional athletes. This may raise concerns about the generalizability of our findings; however, our ultrasonographic findings were consistent with previous literature.[5,7] In particular, professional athletes may also be under substantial pressure to avoid negative career events and outcomes and therefore underreport the presence of ulnar nerve symptoms. The primary goal of this study was to determine the validity of physical examination compared with ultrasound for detecting cubital tunnel ulnar nerve instability. Even if factors such as sex and athleticism influenced the sample prevalence of ulnar nerve subluxation, estimates of sensitivity and specificity would not be impacted because these properties are independent of prevalence. The lack of ulnar nerve symptoms in this population precludes the potential identification of clinically meaningful subluxation. A larger study would be needed to capture and assess associations with symptomatic ulnar nerves. Methodological limitations include the use of single physical and sonographic examiners. In addition, sonographic examination of the ulnar nerve at the cubital tunnel requires a certain skill level with ultrasound, and reliable detection is operator-dependent. However, the moderate reliability of physical examination reported by previous authors raises similar concerns about physical examination,[2] and Endo et al[7] reported high intra- and interobserver reliability of sonographic measurements (0.95 and 0.91, respectively). Last, ultrasound equipment represents a capital expenditure, and the cost of this technology may be prohibitive to certain providers. There are also certain settings, such as the operating room, where obtaining an ultrasound with little notice may be difficult or impossible. For these reasons, physical examination remains important, and its practical utility cannot be discounted.

CONCLUSION

Physical examination had moderate sensitivity and high specificity for detecting ulnar nerve subluxation at the cubital tunnel of the elbow when using ultrasound as a reference. These findings suggest that when detecting the presence of a subluxating ulnar nerve is most important, it may be advisable to obtain an ultrasound evaluation instead of relying on physical examination. However, physical examination alone may be appropriate for ruling out subluxation.

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