Clinical Assessment of the Ulnar Nerve at the Elbow: Reliability of Instability Testing and the Association of Hypermobility with Clinical Symptoms

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Background: Ulnar nerve hypermobility has been reported to be present in 2% to 47% of asymptomatic individuals. To our knowledge, the physical examination technique for diagnosing ulnar nerve hypermobility has not been standardized. This study was designed to quantify the interobserver reliability of the physical examination for ulnar nerve hypermobility and to determine whether ulnar nerve hypermobility is associated with clinical symptoms.

Methods: Four hundred elbows in 200 volunteer participants were examined. Each participant was queried regarding symptoms attributable to the ulnar nerve. Three examiners, unaware of reported symptoms, independently performed a standardized examination of both elbows to assess ulnar nerve hypermobility. Ulnar nerves were categorized as stable or as hypermobile, which was further subclassified as perchable, perching, or dislocating. Provocative maneuvers, consisting of the Tinel test and flexion compression testing, were performed, and structural measurements were recorded. Kappa values quantified the examination's interobserver reliability. Unpaired t tests, chi-square tests, Wilcoxon tests, and Fisher exact tests were utilized to compare data between those with hypermobile nerves and those with stable nerves.

Results: Ulnar nerve hypermobility was identified in 37% (148) of the 400 elbows. Hypermobility was bilateral in 30% (fifty-nine) of the 200 subjects. For the three examiners, weighted kappa values on the right and left sides were 0.70 and 0.74, respectively. Elbows with nerve hypermobility did not experience a higher prevalence of subjective symptoms (snapping, pain, and tingling) than did elbows with stable nerves. Provocative physical examination testing for ulnar nerve irritability, however, showed consistent trends toward heightened irritability in hypermobile nerves ($p = 0.04$ to 0.16). Demographic data and anatomic measurements were similar between the subjects with stable nerves and those with hypermobile nerves.

Conclusions: Ulnar nerve hypermobility occurs in over one-third of the adult population. Utilizing a standardized physical examination, a diagnosis of ulnar nerve hypermobility can be established with substantial interobserver reliability. In the general population, ulnar nerve hypermobility does not appear to be associated with an increased symptomatology attributable to the ulnar nerve.

Clinical Relevance: The results of this study demonstrate the reliability of clinically diagnosing ulnar nerve hypermobility and the lack of association of ulnar nerve hypermobility with symptoms.

Ulnar nerve hypermobility at the elbow is a recognized finding in an otherwise asymptomatic subject. Prior studies of clinical examination and advanced imaging techniques have documented increased nerve mobility in 2% to 47% of the population[1-5] and have classified the nerves that shift onto the medial epicondyle as subluxing or incomplete and those that translate completely over the medial epicondyle as dislocating or complete[2,4]. Recent investigations utilizing dynamic

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ultrasonography and magnetic resonance imaging (MRI) have estimated the prevalence of nerve hypermobility to be in the range of 2% to 27% but have not correlated this finding with clinical symptoms[1-3].

As the utilization of in situ ulnar nerve decompression as a treatment for cubital tunnel syndrome has increased, concerns have arisen regarding the potential for worsening or creating symptomatic ulnar nerve hypermobility[6-9]. Consequently, the ability to accurately detect dynamic instability has become increasingly relevant during the clinical examination. Advanced imaging techniques are not practical or economically feasible in the clinic setting and, to our knowledge, the physical examination technique for diagnosing ulnar nerve instability has not been standardized.

This study was designed to quantify the interobserver reliability of the physical examination for ulnar nerve hypermobility and to determine the association of hypermobility with patient-reported symptoms. Secondary goals of the investigation were to establish the prevalence of ulnar nerve hypermobility in a sample of the normal population and to identify demographic and/or structural corollaries with nerve hypermobility. Our hypotheses were that a careful clinical examination would demonstrate high interobserver reliability between trained observers, and subjects with hypermobile ulnar nerves would have more subjective symptoms, with a higher rate of positive provocative physical examination maneuvers compared with subjects with stable ulnar nerves. We also hypothesized that elbows with increased cubital valgus and increased arcs of elbow flexion and extension would demonstrate a greater prevalence of ulnar nerve hypermobility.

Materials and Methods

We obtained institutional review board approval for this prospective investigation, and informed consent was obtained from each patient. The investigation was conducted in an outpatient pediatric orthopaedic clinic. Adult (eighteen years of age or older) family members who accompanied patients were recruited to participate. We provided no incentive for participation. Once a subject consented, a brief screening assessment was performed. Subjects with a history of elbow trauma, previous elbow surgery, previous surgery of the upper-extremity nerve (aside from carpal tunnel release), or any upper-extremity congenital anomaly were excluded. Only one eligible subject declined participation.

Four hundred elbows in 200 volunteer participants were examined. Fifty-six subjects (28%) were male and 144 (72%) were female, with a mean age of forty-two years (range, eighteen to eighty-eight years). One hundred and eighty-two subjects (91%) were right-hand dominant, and 177 subjects (89%) were white.

Ulnar Nerve Mobility Testing

Prior to initiating patient enrollment, the examining hand surgeons met to standardize the clinical evaluation technique.

Examination of the ulnar nerve began with visual inspection for gross ulnar nerve dislocation as the patient actively flexed and extended the elbow. Next, the examiner palpated the elbow to identify the proximal, posteromedial aspect of the medial humeral epicondyle and to identify the nerve in or about the cubital tunnel. The examiner then removed his or her finger from the medial humeral epicondyle while the subject actively flexed the elbow with the forearm in supination. When the elbow was at maximum flexion, the examiner replaced his or her finger on the proximal, posteromedial aspect of the medial humeral epicondyle (Fig. 1) and the patient then actively extended the elbow. If the ulnar nerve was trapped anterior to the examiner's finger, the nerve was judged to *dislocate.* If the nerve was beneath the examiner's finger, the nerve was judged to *perch* on the medial humeral epicondyle. If the nerve was not palpated, the nerve was judged to be *stable* in its groove. This step was repeated as necessary to allow differentiation of synovium, triceps, and subcutaneous tissue from the ulnar nerve. Finally, with the elbow in midflexion, the examiner gently grasped the nerve in an effort to discern whether the nerve could be manipulated out of its groove onto the medial humeral epicondyle for classification as a *perchable* nerve.

Three examiners, including two attending hand surgeons (C.A.G. and P.R.M.) and one fellow in hand surgery (M.O.V.S.), independently examined both elbows of all subjects as described above. Examiners were unaware of any symptoms reported by the subjects. The order in which the examiners evaluated each subject varied.

Assessment of Symptoms and Provocative Testing

A research coordinator asked each subject three questions regarding the presence of elbow symptoms (Table I).

Additionally, one examiner (an attending hand surgeon [C.A.G.]) performed provocative maneuvers on each patient. A Tinel test[10] was performed at the cubital tunnel by firmly tapping between the posteromedial olecranon and the medial humeral epicondyle (over the cubital tunnel) with the elbow in 45° of flexion, as well as 3 cm proximal and distal to this point over the ulnar nerve. A positive test was documented if the patient reported a tingling sensation radiating to the small finger from at least one location. An elbow flexion compression test[11] was performed with manual pressure directly applied over the ulnar nerve between the posteromedial olecranon and medial humeral epicondyle while the elbow was maximally flexed. Care was taken to ensure the ulnar nerve was under the exam-

TABLE I Questions Regarding Ulnar Nerve Symptoms

1. Do you have pain on the inside of your elbow?* If so, how often?
2. Do you have snapping (or catching) on the inside of your elbow?* If so, how often?
3. Do you have tingling (or an electrical sensation) in your ring or small finger? If so, how often?

*"Inside of your elbow" was demonstrated to reflect symptoms on the posteromedial side of the elbow over the cubital tunnel.

Fig. 1

Examination technique. The examiner places his or her thumb on the posteromedial aspect of the medial humeral epicondyle (red circle) at maximum elbow flexion. The patient then extends the elbow as the examiner assesses nerve stability.

iner's fingers during this maneuver. A positive test was documented if the patient reported a tingling sensation radiating to the small finger or pain about the elbow or medial forearm within sixty seconds.

Baseline Structural Assessment

Detailed structural measurements were recorded for both elbows of each subject. We evaluated the carrying angle of the elbow using a goniometer (Sammons Preston, Bolingbrook, Illinois) placed on the anterior surface of the fully extended elbow with the shoulder adducted and the forearm supinated. Elbow flexion-extension was measured in similar fashion with the shoulder adducted and the forearm supinated. Forearm rotation (pronation and supination) was assessed at the distal forearm level with the shoulder adducted and the elbow flexed 90°. Grip strength was recorded with the elbow flexed 90° and the shoulder adducted to the side with use of a Jamar dynamometer (Asimow Engineering, Los Angeles, California). Manual muscle testing was performed to assess the strength of the flexor digitorum profundus to the small finger, the first dorsal interosseous muscle, and the abductor pollicis brevis muscle. Strength was graded on the British Medical Council scale from 1 to 5, with 5 representing full strength[12]. Two-point discrimination was assessed for the index and small fingers.

Statistical Analysis

The prevalence of ulnar nerve hypermobility (perchable, perching, or dislocating) was determined from consensus rating by two of the three examiners. We considered nerves that were perchable, perching, or dislocating to be hypermobile and all others to be stable.

Ninety-five percent Wald confidence intervals were calculated for both the estimated overall prevalence of nerve hypermobility and degrees of hypermobility.

Data were analyzed to determine the interobserver reliability of the standardized physical examination for ulnar nerve hypermobility. Examination ratings were divided into stable, perched (perchable or perching), and dislocating. For the comparison of all three raters with each other, each pairwise comparison of raters was created, resulting in 600 observations per side. Weighted kappa values were calculated for this three-category ordinal rating system. Although not corrected for chance agreement, we also determined overall percent agreement between examiners. This analysis was repeated to compare the performance of the physical examination by only the two senior examiners (C.A.G. and P.R.M.) as well as for a collapsed dichotomous scale of ulnar nerve hypermobility (stable versus hypermobile).

Characteristics of the subjects were evaluated against the presence or absence of ulnar nerve hypermobility by side. Variables evaluated included demographics, reported symptoms, physical examination measurements, and results of provocative maneuvers. Two hundred right and 200 left elbows were analyzed independently as examination of the elbows bilaterally was not thought to equate with 400 independent elbow observations. Statistical analysis was conducted to compare data between subjects with normal ulnar nerves and those with abnormal ulnar nerves defined by at least two of three raters indicating nerve hypermobility. Continuous variables (subject age, pronation, and grip strength) were analyzed with unpaired Student t tests, while elbow flexion, elbow extension, supination, carrying angle, and pinch strength underwent Wilcoxon testing because of non-normal data distribution. Categorical variables (sex; race; hand dominance; presence of elbow hyperextension; presence of snapping, pain, and/or tingling; a positive Tinel test; and positive elbow flexion compression test) were analyzed by the chi-square test while the presence or absence of two-point discrimination of >5 mm was analyzed by the Fisher exact test because of its limited occurrence.

The study population of 200 individuals (400 elbows) was a convenience sample based on available resources. After data collection on the first 100 subjects was done, a power analysis was conducted to determine the necessary sample size for detecting clinically important differences in outcome variables of primary interest. In order to detect a 50% increase in symptoms attributable to the ulnar nerve with a 15% prevalence of positive findings in stable nerves, we would have needed 424 subjects per group (stable versus hypermobile). However, enrollment was sufficient ($\beta > 0.9$, $\alpha < 0.05$) to adequately detect what we believed to be clinically important structural differences (a 10° difference in elbow flexion-extension as well as a 5° difference in elbow carrying angle) that we hypothesized were associated with ulnar nerve hypermobility.

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Results

Ulnar nerve hypermobility, defined by consensus of at least two of three examiners, was identified in 37% (148) of the 400 elbows examined. Thirty percent (fifty-nine) of all 200 subjects examined, or 67% of the eighty-eight subjects with nerve hypermobility on one side, demonstrated bilateral hypermobility. Seven percent (twenty-six) of 400 nerves dislocated with elbow flexion. Dislocation of the ulnar nerve was bilateral in 4% (eight subjects) of the total group and in 47% of those with at least one dislocating nerve.

TABLE II Pairwise Comparison Data for Three Examiners on Right Ulnar Nerves*

	Second Rating: Stable	Second Rating: Perch‡	Second Rating: Dislocate	Agreement Statistics†
First rating				84%; 0.70 (0.65-0.76)
Stable	**368**	43	1	
Perch‡	30	**112**	5	
Dislocate	0	18	**23**	

*Six hundred ratings (200 ratings by each of three examiners) compare the observations of the examiners pairwise (i.e., examiner 1 versus 2, 1 versus 3, and 2 versus 3). Bold values indicate observations in agreement. †The values are given as the percent agreement and the weighted kappa with the 95% confidence interval in parentheses. ‡Perch combines perchable and perching.

The physical examination for determination of ulnar nerve hypermobility demonstrated substantial interobserver reliability (Table II)[13]. For the three examiners, weighted kappa values on the right and left sides were 0.70 (95% confidence interval [95% CI], 0.65 to 0.76) and 0.74 (95% CI, 0.69 to 0.79), respectively. Kappa values minimally improved (0.72 for the right side and 0.74 for the left) when reliability was determined on the basis of a dichotomous nerve categorization (stable compared with hypermobile). Interobserver reliability was not improved when only the level of agreement between the two senior examiners (C.A.G. and P.R.M.) was analyzed. The overall percent agreement among examiners, not correcting for agreement expected by chance, was 84% when stable, perching, or dislocating nerves were identified. The percent agreement was 88% when stable compared with hypermobile nerves were determined.

Elbow snapping was reported to occur in 9% (thirty-four) of the examined elbows. Only 38% (eight of twenty-one right elbows and five of thirteen left elbows) of the thirty-four elbows that had snapping were diagnosed as having hypermobile ulnar nerves. Nine percent of subjects (thirty-six elbows) reported subjective posteromedial elbow pain, and 15%

TABLE III Patient Symptoms as a Function of Ulnar Nerve Mobility

Characteristic	Right*: Stable (N = 136)	Right*: Hypermobile (N = 64)	Right*: P Value	Left*: Stable (N = 116)	Left*: Hypermobile (N = 84)	Left*: P Value
Snapping present	13 (10)	8 (13)	0.53	8 (7)	5 (6)	0.79
Pain present	17 (13)	5 (8)	0.32	11 (9)	3 (4)	0.11
Tingling present	20 (15)	10 (16)	0.87	17 (15)	11 (13)	0.75

*Data are given as the number of patients, with the percentage in parentheses.

TABLE IV Positive Provocative Maneuvers as a Function of Ulnar Nerve Mobility

	Right*			Left*		
Characteristic	Stable (N = 136)	Hypermobile (N = 64)	P Value	Stable (N = 116)	Hypermobile (N = 84)	P Value
Tinel sign	19 (14)	14 (22)	0.16	16 (14)	21 (25)	0.04
Elbow flexion compression test	15 (11)	13 (20)	0.08	13 (11)	16 (19)	0.12

*Data are given as the number of patients, with the percentage in parentheses.

(fifty-eight) of subjects described "tingling" in the small or ring fingers on questioning. Elbows with nerve hypermobility did not experience a higher prevalence of subjective symptoms (snapping, pain, or tingling) (Table III). Despite failing to reach significance, the findings on provocative physical examination testing demonstrated a consistent pattern in right and left elbows, with each having more positive Tinel and flexion compression testing in hypermobile nerves (Table IV).

Individuals with hypermobile ulnar nerves were similar in terms of demographic characteristics (sex, hand dominance,

TABLE V Subject Demographics and Baseline Examination Measurements as a Function of Nerve Mobility

	Right			Left		
Characteristic	Stable (N = 136)	Hypermobile (N = 64)	P Value*	Stable (N = 116)	Hypermobile (N = 84)	P Value*
Sex†			0.30			0.02
Female	101 (74)	43 (67)		91 (78)	53 (63)	
Male	35 (26)	21 (33)		25 (22)	31 (37)	
White†	123 (90)	54 (84)	0.21	105 (91)	72 (86)	0.29
Right-hand dominant†	125 (92)	58 (91)	0.76	107 (92)	76 (90)	0.66
Age‡ *(yr)*	42 ± 13	43 ± 14	0.78	42 ± 13	42 ± 14	0.95
Abductor pollicis brevis†§	136 (100)	64 (100)	NA	115 (99)	84 (100)	NA
First dorsal interosseous†§	136 (100)	64 (100)	NA	115 (99)	84 (100)	NA
Flexion‡ *(deg)*	141 ± 8 (140)	143 ± 6 (142)	0.07#	141 ± 7 (140)	142 ± 6 (140)	0.45#
Extension‡ *(deg)*	4 ± 6 (0)	3 ± 4 (0)	0.24#	3 ± 4 (0)	3 ± 4 (0)	0.78#
Extension of >0°†	58 (43)	21 (33)	0.20	46 (40)	32 (39)	0.88
Pronation‡ *(deg)*	82 ± 5 (82)	82 ± 5 (80)	0.77	83 ± 5 (84)	82 ± 5 (80)	0.11#
Supination‡ *(deg)*	82 ± 6 (82)	83 ± 5 (84)	0.07#	83 ± 5 (82)	83 ± 5 (82)	0.60#
Carrying angle‡ *(deg)*	10 ± 4 (10)	9 ± 3 (9)	0.005#	10 ± 4 (10)	10 ± 4 (9)	0.32#
Grip‡ *(kg)*	33 ± 14	34 ± 15	0.62	31 ± 13	35 ± 13	0.05
Pinch‡ *(kg)*	9 ± 4 (8)	9 ± 3 (8)	0.79#	8 ± 4 (8)	9 ± 3 (7.7)	0.49#
2-point discrimination‡ *(mm)*	5.1 ± 0.7 (5)	5.0 ± 0.2 (5)	0.78#	5.0 ± 0.6 (5)	5.0 ± 0.5 (5)	0.92#
2-point discrimination of >5 mm†	11 (8)	3 (5)	0.55**	10 (9)	4 (5)	0.29**

*P values compare the normal elbows with those that are not normal by chi-square test (for categorical variables) or unpaired t test (for continuous variables), unless otherwise noted. NA = not applicable. †The values are given as the number of subjects, with the percentage in parentheses. ‡The values are given as the mean and the standard deviation, with the median in parentheses. §The muscles had normal findings, with full (grade-5) strength on the British Medical Council scale[12]. #P value by Wilcoxon test. **P value by Fisher exact test.

TABLE VI Data Comparison of Characteristics After Exclusion of Perchable Nerves from Hypermobile Category

	Right			Left		
Characteristic	Stable (N = 136)	Hypermobile (N = 64)	P Value	Stable (N = 116)	Hypermobile (N = 84)	P Value
Patients with perchable nerve considered stable	152	48		146	54	
Snapping present*						
Before exclusion	13 (10)	8 (13)	0.53	8 (7)	5 (6)	0.79
After exclusion	15 (10)	6 (12.5)	0.60	10 (7)	3 (6)	0.742
Pain present*						
Before exclusion	17 (13)	5 (8)	0.32	11 (9)	3 (4)	0.11
After exclusion	17 (11)	5 (10)	0.882	12 (8)	2 (4)	0.267
Tingling present*						
Before exclusion	20 (15)	10 (16)	0.87	17 (15)	11 (13)	0.75
After exclusion	22 (14.5)	8 (17)	0.711	19 (13)	9 (17)	0.532
Positive Tinel test*						
Before exclusion	19 (14)	14 (22)	0.16	16 (14)	21 (25)	0.04
After exclusion	26 (17)	7 (15)	0.682	26 (18)	11 (20)	0.679
Positive elbow flexion compression test*						
Before exclusion	15 (11)	13 (20)	0.08	13 (11)	16 (19)	0.12
After exclusion	18 (12)	10 (21)	0.118	20 (14)	9 (17)	0.597
Flexion† *(deg)*						
Before exclusion	141 ± 8	143 ± 6	0.07	141 ± 7	142 ± 6	0.45
After exclusion	141 ± 8	144 ± 5	0.007	141 ± 7	143 ± 5	0.005
Extension† *(deg)*						
Before exclusion	4 ± 6	3 ± 4	0.24	3 ± 4	3 ± 4	0.78
After exclusion	3 ± 6	3 ± 4	0.487	3 ± 5	3 ± 4	0.476
Carrying angle† *(deg)*						
Before exclusion	10 ± 4	9 ± 3	0.01	10 ± 4	10 ± 4	0.32
After exclusion	10 ± 4	9 ± 3	0.039	10 ± 4	10 ± 4	0.551

*Data are given as the number of patients with the percentage in parentheses. †Data are given as the mean and the standard deviation.

and age) to those with stable ulnar nerves. Baseline physical examination measurements of elbow motion, carrying angle, strength, two-point discrimination, and intrinsic muscle strength failed to demonstrate any consistent differences for the elbows with hypermobile ulnar nerves (Table V). Two significant differences (an increased number of male subjects with a hypermobile left ulnar nerve and a decrease in the carrying angle of right elbows with a hypermobile ulnar nerve) were observed but not substantiated by findings in the contralateral elbow.

To determine if perchable nerves would have been more accurately included within the stable nerve category, data were reanalyzed after characterizing ulnar nerve hypermobility to include only perching and dislocating nerves. In this reanalysis, hypermobile nerves were no more likely to be associated with increased symptoms reported by the subjects. Similarly, physical examination measures showed no clinically important differences between groups despite a significant increase in elbow flexion among the hypermobile nerve group ($p < 0.01$) (Table VI).

Discussion

As prior investigations into the prevalence of ulnar nerve hypermobility have relied on single examiners and have not explicitly defined the method of clinical examination[4,5], the interobserver reliability of this diagnostic maneuver had not been determined. To our knowledge, the current investigation is the first to examine the interobserver reliability of physical examination for ulnar nerve hypermobility and to quantify the relationship between ulnar nerve hypermobility and symptomatology. The current data demonstrate substantial, yet imperfect, consistency between examiners. Notably, the high degree of interobserver agreement in this investigation represents an idealized situation in which the method of examination itself was explicitly defined and standardized among examiners.

Discordant classification of nerve stability by experienced clinicians in this study suggests that, at times, it is difficult to assess the mobility of the ulnar nerve within the cubital tunnel. There are several challenges that are noted during the physical examination that each examiner worked to minimize. First, some patients have substantial soft tissue at the medial aspect of the elbow, making direct palpation of the nerve challenging. In some patients, the abundant soft tissue can be displaced anterior to the medial epicondyle, allowing the examiner's thumb to be placed on the epicondyle. Our collection of baseline physical examination data did not include measurements to determine body mass index (BMI). Thus, we cannot comment on the effect of increasing BMI on the level of agreement between examiners. However, at the conclusion of this study, examiners noted increased difficulty with the examination on the basis of the distribution of fatty tissue around the elbow as opposed to overall patient size. Second, the triceps muscle was found to vary in size and mobility, a finding that necessitated careful palpation during the examination. We found that experience with the examination technique and the act of repeating an individual's elbow examination as necessary assisted examiners when faced with these challenges.

The prevalence of ulnar nerve hypermobility (37%) and dislocation (7%) in this study was higher than expected[4,5]. However, the relatively higher frequency of perching relative to dislocation is consistent with prior reports in the literature[2,4,5,14]. We suspect that our investigational methods may have contributed to our findings. It is most likely that our inclusion of so-called perchable nerves represents a portion of the population that was not captured in prior investigations. Only Ashenhurst[5] incorporated a similar category of *hypermobile* nerves defined by the ability of the examiner to displace the ulnar nerve out of the ulnar groove. The categories of ulnar nerve hypermobility defined in this investigation were chosen on the basis of the degrees of hypermobility that impact the authors' surgical decision making.

When considering surgery for cubital tunnel syndrome, the authors consider in situ decompression acceptable for stable nerves. As nerves begin to perch on the medial epicondyle, the authors discuss with their patients the risk of increased hypermobility after decompression that could necessitate conversion to either anterior transposition of the ulnar nerve or medial epicondylectomy. The nerves that dislocate on physical examination are treated primarily with ulnar nerve transposition or epicondylectomy. If we had excluded perchable nerves from our subject group, the overall prevalence of hypermobility was 26% and the data would more closely correlate with those of Ozturk et al., who documented subluxation in 23% and dislocation in 8.5% of 212 elbows[14]. The high degree of bilateral hypermobility that was noted supports a similar finding by Ashenhurst[5].

We suggest that the perchable nerve, one that can be actively displaced from its groove, is best categorized as a hypermobile ulnar nerve. To ensure that we were not obscuring true differences between stable nerves and the perching and/or dislocating nerves, we performed statistical testing with the perchable nerves grouped first with the hypermobile nerves and second with the stable nerves. We believed this reanalysis to be necessary as some would contend that a nerve is not truly hypermobile if it does not displace along the medial epicondyle in the absence of examiner intervention. However, our results were minimally affected (Table VI).

When planning this study, we predicted that ulnar nerve hypermobility would be associated with increased rates of patient symptoms, positive provocative examination findings, and increased elbow carrying angles. However, the data failed to demonstrate significant differences in subject demographics, symptomatology, ulnar nerve irritability, or objective physical examination measurements. Our data confirm the finding of Childress who reported the predominantly asymptomatic nature of the hypermobile nerve in the normal population[4].

As examinations of the elbows were conducted bilaterally, we were able to collect data for right and left elbows. For each study subject, right and left elbows are generally expected to be similar in structure (range of motion and carrying angle). Taking into account the fact that examination of the elbows bilaterally does not produce truly independent observations, data from right and left elbows of each subject were analyzed separately as opposed to presenting an interpretation of 400 elbows. Therefore, our results focused on differences both attributable to nerve hypermobility and consistent between right and left sides.

Our study has several limitations. Those enrolled were not seeking medical care for ulnar nerve symptoms. The examination of individuals who are not patients is advantageous in that they are expected to represent the population at large and thus provide a truer estimate of the association between the physical examination findings and symptoms than does a sample drawn from patients with cubital tunnel syndrome. However, our recruitment of accompanying family members in the office resulted in a predominance of females in our sample. Thus, our conclusions regarding the association of nerve hypermobility with the subjects' symptoms and anatomic measurements may not be generalized to patients presenting with ulnar nerve complaints and are potentially biased by the sex discrepancy. As all investigators were aware of the study aims, we attempted to minimize bias in the examination by keeping the examining surgeons unaware of patient symptoms. However, it is possible that examiner bias impacted our estimated prevalence of bilateral nerve hypermobility. As subjects were examined bilaterally at a single visit, examiners were aware of findings on the first elbow examined when approaching the contralateral elbow. Identifying a hypermobile nerve on one side may have increased the examiner's scrutiny when examining the contralateral side. As the examination could begin on either the right or left side and examiners were allowed to revisit the initial side if needed, we expect that this bias may have increased the number of patients with positive findings bilaterally but not have disproportionately affected the estimated prevalence of hypermobility on the right or left side individually.

This investigation did not incorporate any diagnostic imaging (ultrasound or MRI) to serve as a reference comparison for the physical examination. Had imaging been performed, we may have been able to comment on the so-called accuracy of the clinical diagnosis of ulnar nerve hypermobility in addition to our assessment of interobserver reliability. However, this assumes that either ultrasound or MRI is the so-called gold standard in documenting ulnar nerve hypermobility; we believe that these imaging studies are problematic for several reasons. First, no study has determined the accuracy of such imaging compared with surgical findings. Ultrasound is operator-dependent and MRI varies in quality, making these modalities imperfect. Additionally, while both modalities may detect frank nerve dislocation, nerve perching or subtle nerve motion may not be detected. Second, in addition to the shortcomings of these imaging techniques, the authors' clinical practices base the diagnosis of ulnar nerve hypermobility solely on clinical examination. These imaging studies are costly and not routinely utilized in the current medical environment. Thus, we chose to focus this investigation on the clinical diagnosis of ulnar nerve hypermobility and to define the interobserver reliability of an explicitly defined examination, accepting the lack of a diagnostic reference.

Because of the low prevalence of symptoms reported by study subjects with both stable and hypermobile nerves, our sample of 200 subjects remained limited in power. Provided that statistical limitation, we acknowledge that if our data reflected what we had determined would be a clinically relevant increase in symptoms (a 50% increase), our statistical testing would have failed to show significance. However, our data did not suggest any increased prevalence of subjective symptoms attributable to ulnar nerve hypermobility. For this reason, it is unlikely that increasing the number of subjects examined would have identified a clinically important relationship between nerve hypermobility and these subjective symptoms. However, the Tinel sign and elbow flexion compression test demonstrated a consistent pattern toward increased nerve irritability with hypermobility. In this case, a larger sample size may have allowed both tests to demonstrate a significant difference between groups.

In summary, when an explicitly defined physical examination technique is used, a demonstration of ulnar nerve hypermobility can be made with substantial interobserver reliability. Ulnar nerve hypermobility does not appear to be associated with an increased prevalence of symptoms in an otherwise normal individual. ■

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