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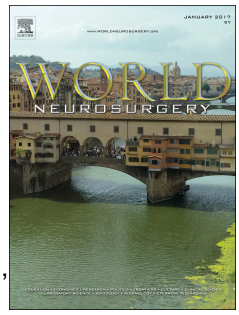

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The Window Test: a simple bedside method to detect radial deviation of the wrist commonly seen in posterior interosseous nerve palsy

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Key Words

brachial plexus, neuropathy, posterior interosseous nerve, posterior interosseous nerve palsy, radial deviation of the wrist, window test

Running head: Window Test for PINP
Declarations of interest: none

Abstract

Background: Posterior interosseous nerve palsy (PINP) is a disorder caused by damage to the posterior interosseous nerve, resulting in weak extension of the wrist and fingers as well as radial deviation of the wrist. *Methods:* In this study, a new type of evaluation for PINP was analyzed in hopes of increasing ease of diagnosis and earlier detection of the disorder. The "Window Test" is performed by the examiner laying hands on the ulnar aspect of the patient's pronated forearm while the latter is trying to extend the wrist. A positive test is observed when a gap (window) appears between the examiner's forearm and the patient's hand. Lay people, medical students, residents, and practicing providers were assessed prospectively on their ability to correctly diagnose PINP by observing one hand, both hands, and by using the Window Test. *Results:* The Window Test was consistently found to be the most effective method of evaluation as it increased the accuracy of diagnoses in all groups surveyed. Additionally, case studies were performed using the Window Test on patients, further demonstrating the efficacy of the test by confirming wrist radial deviation. *Conclusion:* The Window Test introduces a reference frame, making it easier to assess wrist radial deviation and offering a simple evaluation that can be administered by virtually anyone. These findings indicate that the implementation of the Window Test will increase the accuracy and effectiveness of PINP diagnosis, thus allowing early diagnosis and better management.

Key Words: brachial plexus, neuropathy, posterior interosseous nerve, posterior interosseous nerve palsy, radial deviation of the wrist, window test

INTRODUCTION

Posterior interosseous nerve palsy (PINP) is a syndrome that results from damage to the posterior interosseous nerve (PIN), causing weakness in wrist and finger extension in addition to wrist radial deviation. It also results in weakness of abductor pollicis longus (APL). The PIN is the continuation of the deep branch of the radial nerve within the proximal forearm.[1] It passes between the two heads of the supinator and supplies extensors to the wrist and fingers as well as APL.[2] Compression, nerve injury, and inflammation of the PIN are among the most common etiologies of PINP.[3, 4] Other causes include ganglion cysts and tumors, including lipomas.

PINP patients often experience weakness or, in severe cases, paralysis of the wrist and digital extensors. When patients attempt to extend the wrist, the result is often a weak extension with radial deviation.[1] This is explained by the preservation of the radial extensors of the wrist, which originate proximal to the PIN. PINP patients sometimes experience pain, generally not as a primary symptom, though previous fractures or trauma to the PIN may increase the severity of symptoms.[1] Patients may also experience popping sensations and paresthesias. Additionally, PINP patients do not experience any cutaneous sensory loss due to a lack of dermatomal supply.[5]

PINP is a rare though often treatable neuropathy with an annual incidence of approximately 0.003%.[6] The male to female ratio is 2:1, and the right arm is twice as likely to be affected as the left arm.[1] Difficulties in the diagnosis of PINP partially arise from the occasionally slow onset of symptoms, leading to an average 2-3 years before a definitive diagnosis is made.[7] In addition to the slow development of the syndrome, PINP may be difficult to differentiate from lateral epicondylitis and cervical radiculopathy.[8]

Currently, clinical and electrophysiological examinations are used to diagnose PINP. The lack of accuracy and efficiency in its diagnosis, however, suggests that there is a need for an evaluation that is tailored more specifically to the PINP. The Window Test introduces a new approach to the physical examination of PINP that could potentially increase the accuracy of

clinical diagnosis. Occasionally more proximal lesions, such as a brachial plexus injury or a partial/recovering radial nerve injury, may present with a PINP-like picture, predominantly presenting with radial deviation during wrist extension. The Window Test was found useful in those cases as well, as is evident from our case illustrations.

METHODS

Window Test

The Window Test is a bedside confrontation test used to clinically assess patients with PINP. With the examiner seated in front of the patient, the latter is asked to extend both wrists with the forearms pronated. The clinician then places the palmar aspect of her/his wrists onto the ulnar aspect of the patient's wrists (**Fig. 1C** and Supplementary **video 1**). The Window Test is positive when a gap (window) appears between the examiner's forearm and the patient's affected hand, thus demonstrating radial deviation of the wrist.

Evaluation of Window Test

Thirty-one individuals were randomly selected including practicing providers (n = 5), residents (n = 6), medical students (n = 4), and lay people (n = 16), including 13 undergraduate students. The first author was examined, simulating a PINP (radial deviation with wrist extension). Participants were blinded as to what they were being tested on and were briefly taught how to perform the Window Test. Participants were asked if they were able to observe any abnormalities, first by observing one hand, second by comparing both hands, and third by using the Window Test. After testing, participants were asked to rate how useful the Window Test was for diagnosing radial deviation of the wrist, and therefore PINP. Each participant graded the usefulness of the Window Test using a scale of 1-4, where 1 is not useful, 2 somewhat useful, 3 useful, and 4 very useful.

Clinical Assessment

The Window Test has been used by the first author for over 5 years with consistently satisfactory results in detecting radial deviation of the wrist. Three illustrated case examples are provided here, representing various levels of injury. A fourth case of complete radial nerve palsy is provided for comparison. Institutional Review Board (IRB) approval was obtained for the clinical cases.

Statistics

The two-tailed Fisher's exact test was used to directly compare two methods within a group of participants being evaluated. One-way ANOVA was used to compare all groups in terms of the usefulness rating (GraphPad Prism 6 Software, San Diego, CA). Differences were considered significant at $p < 0.05$. Quantitative data are presented as mean ± standard error of the mean (SEM).

RESULTS

Thirty-one individuals were assessed in their ability to correctly identify simulated PINP using three different methods: 1) observing one hand, 2) comparing both hands, and 3) using the Window Test (**Fig. 1**). When observing one hand, only 16.1% of participants were able to correctly diagnose PINP. While observing both hands, 38.7% of participants were able to correctly diagnose PINP. When participants used the Window Test, however, 87.1% were able to correctly diagnose PINP, which was a significantly higher rate than that of the one-hand method ($p < 0.0001$) and the two-hand method ($p = 0.0002$; **Fig. 2 A**).

When separating the participants into groups according to their medical background, we observed that 81.3% of lay people, including undergraduate students, were able to correctly

identify radial deviation of the wrist using the Window Test, which was significantly higher than observing one hand (6.3%, $p < 0.0001$) and both hands (38.7%, $p = 0.0038$; **Fig. 2 B**). None of the medical students correctly diagnosed radial deviation when observing one hand, 25% when observing both hands ($p = 0.1429$), and 100% when using the Window Test ($p = 0.0286$; **Fig. 2 C**). While using the Window Test, 83.3% of the residents correctly diagnosed PINP as compared to 33.3% by observing one hand ($p = 0.2424$) and 50% when observing both hands ($p = 0.5455$; **Fig. 2 D**). All practicing providers correctly diagnosed PINP when using the Window Test as compared to 40% by observing one hand ($p = 0.1667$) and 80% when observing both hands ($p = 1.0$; **Fig. 2 E**).

After using the Window Test, all 31 participants were asked to rate its usefulness to diagnose PINP on a scale of 1-4, where 1 is not useful and 4 is very useful. Overall, the participants found the Window Test to be useful with a rating of 3.29 ± 0.156. When separating the participants into groups according to their medical training, there was no significant difference ($p = 0.8917$, **Fig. 3**).

It's worth mentioning that, after less than one minute of instruction, every participant (100%) was able to perform the Window Test without any difficulty, including lay people. This shows the ease of performing the test and teaching it to trainees.

Clinical Assessment

In the clinic, the test has been used by the first author for more than 5 years. Three case illustrations are presented here. Motor strength is presented using the Medical Research Council (MRC) grading system.

Case 1: A 55-year-old female woke up 2 months prior to the office visit with inability to move the right arm associated with numbness. She thought she had slept in a weird position. Motor examination revealed weakness predominantly in the radial nerve distribution. Triceps was 4, supination 4, wrist extension 3 with radial deviation as confirmed by the Window Test (**Fig. 4** and Supplementary **video 1**), extensor pollicis longus 3, extensor digitorum communis 3+, extensor indicis 3. She had a positive Tinel's sign and scratch collapse test over the radial nerve in the spiral groove. Sensation was diminished to light touch in the radial sensory nerve distribution. Electrodiagnostic studies (EDX) revealed right radial mononeuropathy. In summary, this was a 55-year-old female with a 2-month history of right wrist drop, likely a radial nerve palsy as suggested by examination and confirmed by EDX. She had evidence of spontaneous improvement. We continued treating her expectantly.

Case 2: A 74-year-old male with past medical history of heart disease, diabetes, and asthma presented with a 6-month history of left arm weakness. This started with sharp shooting pains in the elbow and forearm, as if stabbed with an ice pack. The pains eventually resolved; however, he was left with significant weakness of the muscles in the left hand and forearm. Later, he noticed significant atrophy of the forearm musculature as well as some of muscles in his hand. There was no preceding trauma, and he had pain at the onset. This was associated with muscle atrophy and inability to extend the fingers.

Examination revealed weakness of the left upper limb, predominantly involving finger extension, and he had left finger drop. Extensor pollicis longus was 4- and extensor digitorum communis 2. Wrist extension was weak and associated with radial deviation as confirmed by the Window Test **(Fig. 5** and Supplementary **video 1**). Sensation was intact to light touch. EDX showed denervation changes in the PIN distribution. In summary, this was a 74-year-old male with left PIN palsy, likely Parsonage-Turner syndrome. Non-operative management was recommended initially. The patient later underwent PIN release.

Case 3: A 17-year-old male was a victim of a motorcycle accident 2 months prior to consultation. He had significant weakness of the right arm that had slowly improved over time. He continued to have significant weakness of the hand intrinsic muscles. He also had a considerable amount of pain. On examination, he had a right-sided Horner's syndrome. He had decreased sensation to light touch over the right C5 and C6 distributions and no sensation over the right C8. Motor examination revealed deltoid was 4+, infraspinatus 4-, subscapularis 3, biceps 2, triceps 4-, wrist extension 4 with radial deviation as confirmed by the Window Test **(Fig. 6)**, wrist flexion 3. Extensor pollicis longus was 1, extensor digitorum communis 3, flexor pollicis longus 0, flexor digitorum profundus to the 2^{nd} and 3^{rd} digits 0, to the 4^{th} and 5^{th} digits 2, flexor digitorum superficialis 0, interossei 1, lumbricals to the 2^{nd}, 3^{rd}, and 4^{th} digits 0, to the 5^{th} digit 1. EDX revealed no motor units in the biceps, first dorsal interosseous, and flexor pollicis longus, and 1 motor unit in the extensor indicis. There were normal sensory nerve action potentials, suggestive of nerve root avulsion at the level of the lower trunk. Cervical spine MRI revealed right C8 pseudomeningocele. In summary, this was a 17-year-old male seen 2 months after a motorcycle accident with right C8 nerve root avulsion, as well as musculocutaneous nerve weakness. Injury had been slowly improving, but he still had significant weakness in the intrinsic hand muscles. The plan was to bring him back to the office with follow up EDX and potentially operative treatment.

Case 4: A 19-year-old male was seen 4 months after motor vehicle crash. He had a right humerus fracture (**Fig. 7A**) that underwent open reduction and internal fixation (**Figs. 7B&C**). Other injuries at the time of the accident included bilateral femur fractures, left pneumothorax, and sternal fracture. On examination, the patient had a complete right wrist drop (**Fig. 7D**). He also had diminished sensation in the radial nerve distribution. When performing the window test, there was no window in the horizontal plane (**Fig. 7E**). A **Reverse Window** (red in **Fig. 7F**) was observed in the sagittal plane, the patient's hand is below the horizontal line made by the

examiner's arm. The blue triangle in **Fig. 7F** shows the normal gap between the extended patient's hand and the examiner's horizontal arm. This is not readily visible by the examiner unless looking in a mirror, otherwise an assistant can be looking from the side. EDX confirmed radial nerve injury at the spiral groove, distal to the triceps branches. The patient is pending surgical exploration.

DISCUSSION

Radial deviation of the wrist may not be so obvious to the examiner by observing one hand. It may become more obvious when comparing to the normal side. We developed the Window Test to provide a good visual to the examiner by observing a gap between the patient's affected hand and the examiner's forearm (**Fig. 1** and Supplementary **video 1**). It is key that the examiner's hands are symmetric in position since wrist extension on only one side could artificially create a false window on that side.

The most common cause of radial deviation of the wrist is PINP. As shown in our case examples, however, it may occur with any higher brachial plexus involvement that preferentially weakens the ulnar extensors. These include partial or recovering high radial nerve or posterior cord injuries. We have objectively demonstrated the utility of the Window Test in diagnosing radial deviation of the wrist by testing it among a widely diverse group from lay people to practicing providers. The test is easy, cheap, available, reproducible, and valid.

About 87% of participants found the Window Test to be either useful or very useful for accurately diagnosing PINP. For lay people, the rate of successful diagnosis using 1 hand, 2 hands, and the Window Test steadily increased from 6.25% to 20% to 80%, respectively. Practicing providers also showed a steady increase from 40% for 1 hand to 80% with 2 hands and finally reached 100% accuracy using the Window Test. Although this was not statistically significant, it's important to note that only the Window Test allowed no provider to miss the diagnosis of PINP.

The main advantage of the Window Test over the one and the two hand observation methods is the introduction of a reference for comparison. The introduction of the observer's arms as a reference point allowed clinicians to recognize and diagnose PINP more proficiently. This is crucial as in the past, PINP could take years to properly diagnose as symptoms worsened.[7] The ability to diagnose more efficiently means more appropriate timely management. The simple nature of the Window Test makes it easy for almost anyone to perform and recognize PINP, including lay people.

The case examples further demonstrate the value of the Window Test. In the first three cases, the Window Test was used to detect wrist radial deviation. This test, in addition to other modalities including EDX, led to the efficient diagnosis of various nerve palsies. Previous reports pointed that PIN entrapment is difficult to diagnose based on physical examination alone, and EDX were necessary to properly understand the presence and severity of injury.[8] The introduction of the Window Test should enhance the clinical diagnosis of PINP. Case number 4 illustrates that in case of complete wrist drop from higher radial nerve palsy, a Reverse Window appears predominantly in the sagittal plane (Fig. 7F) only when the examiner looks in a mirror or an assistant looks from the side. As the examiner looks from above, there is no window (**Fig. 7E**) due to lack of radial deviation observed in PINP. This is obviously in addition to sensory loss in the case of higher radial nerve palsy.

Further, in terms of written and oral boards testing, diagnosing PINP by just observing one hand is the least reliable and should be abandoned as unfair. At least both hands should be provided for comparison, and preferably the Window Test.

Both components of this study, testing people's ability to learn, perform, and interpret the test as well as the clinical cases, were prospectively evaluated. The study has its limitations. First, the first author had to simulate radial deviation, which has its limitations compared to real patients. This was the only way to test lay people who don't have access to patients. Radial

deviation is easy to simulate, especially for an experienced nerve surgeon, and the same person was being tested for consistency across the board. Second, we only discuss 4 representative cases, a very small number. The test has been successfully used by the first author for over 5 years, and these are just case examples to illustrate different levels of injury. The goal was not to present a case series from the surgeon who developed the test but rather raise awareness of the test for people to start using it in their own institutions.

CONCLUSION

The Window Test is a great addition to the clinical armamentarium for diagnosing radial deviation of the wrist. Although this is commonly seen in PINP, this diagnosis can only be confirmed by looking at the patient's history, detailed motor and sensory examination, EDX, and imaging as indicated.

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Figure Legends

Figure 1. Participants were assessed in their ability to correctly diagnose radial deviation with wrist extension by observing one hand (**A**), both hands for comparison (**B**), or the Window Test (white triangle) (**C**). **D-F** simulate complete radial nerve palsy with wrist drop; no triangle is observed in the horizontal plane. Looking from the side or through a mirror, a triangle (red) appears in the sagittal plane, Reverse Window, as compared to the normal window (blue) above the horizontal plane of the examiner's forearm.

Figure 2. Of the 31 people assessed, significantly more were able to correctly diagnose wrist radial deviation using the Window Test as compared to observing one hand or both hands (**A**). Significantly more lay people were able to correctly diagnose radial deviation when using the Window Test as compared to viewing one hand or both hands (n =16, **B**). This group included undergraduate students. Also, significantly more of the medical students were able to correctly diagnose PINP when using the Window Test, as compared to viewing one hand (n = 4, **C**). Only one of the residents misdiagnosed PINP when using the Window Test (n = 6, **D**), and no practicing providers misdiagnosed PINP when using the Window Test (n = 5, **E**). Fisher's Exact Test, *$p<0.05$, **$p<0.01$, ***$p<0.001$, ****$p<0.0001$.

Figure 3. Subjects were asked to rate how useful they considered the Window Test on a scale of 1 to 4, where 1 is not useful, 2 somewhat useful, 3 useful, and 4 very useful. About 87% of people surveyed considered the Window Test to be useful or very useful with an average 3.29 ± 0.156. There was no significant difference between the groups (1-way ANOVA p = 0.8917).

Figure 4. ***Case #1.*** A 55-year-old female consulted for inability to move the right arm. Evaluation included observing one hand (**A**), both hands (**B**), and the Window Test (**C**). Radial deviation was noted using the Window Test and confirmed by EDX suggesting radial nerve palsy.

Figure 5. ***Case #2.*** A 74-year-old male with left arm weakness. Assessment included observing one hand (**A**), both hands (**B**), and the Window Test (**C**). Weak wrist extension and radial deviation was noted using the Window Test and EDX revealed brachial plexopathy, possibly Parsonage-Turner syndrome.

Figure 6. ***Case #3.*** A 17-year-old male underwent consultation and assessment 2 months after a motorcycle accident. Methods of assessment included observing one hand (**A**), both hands (**B**), and the Window Test (**C**). The white triangle between the patient's right hand and the examiner's left forearm demonstrates a positive Window Test and radial deviation of the wrist. EDX revealed possible nerve root avulsion.

Figure 7. Case #4. A 19-year-old male was a victim of motor vehicle accident and sustained a humeral shaft fracture (**A**). He sustained a radial nerve injury as evident by right complete wrist drop (**B**) and confirmed by EDX. When performing the Window Test, no window is observed in the horizontal plane (**C**). However, when looking from the side (**D**), a Reverse Window is seen (red), below the examiner's forearm, as compared to the healthy side (blue).

Abbreviations

EDX: Electrodiagnostic studies
IRB: Institutional Review Board
MRC: Medical Research Council
PIN: Posterior interosseous nerve
PINP: Posterior interosseous nerve palsy
SEM: Standard error of the mean

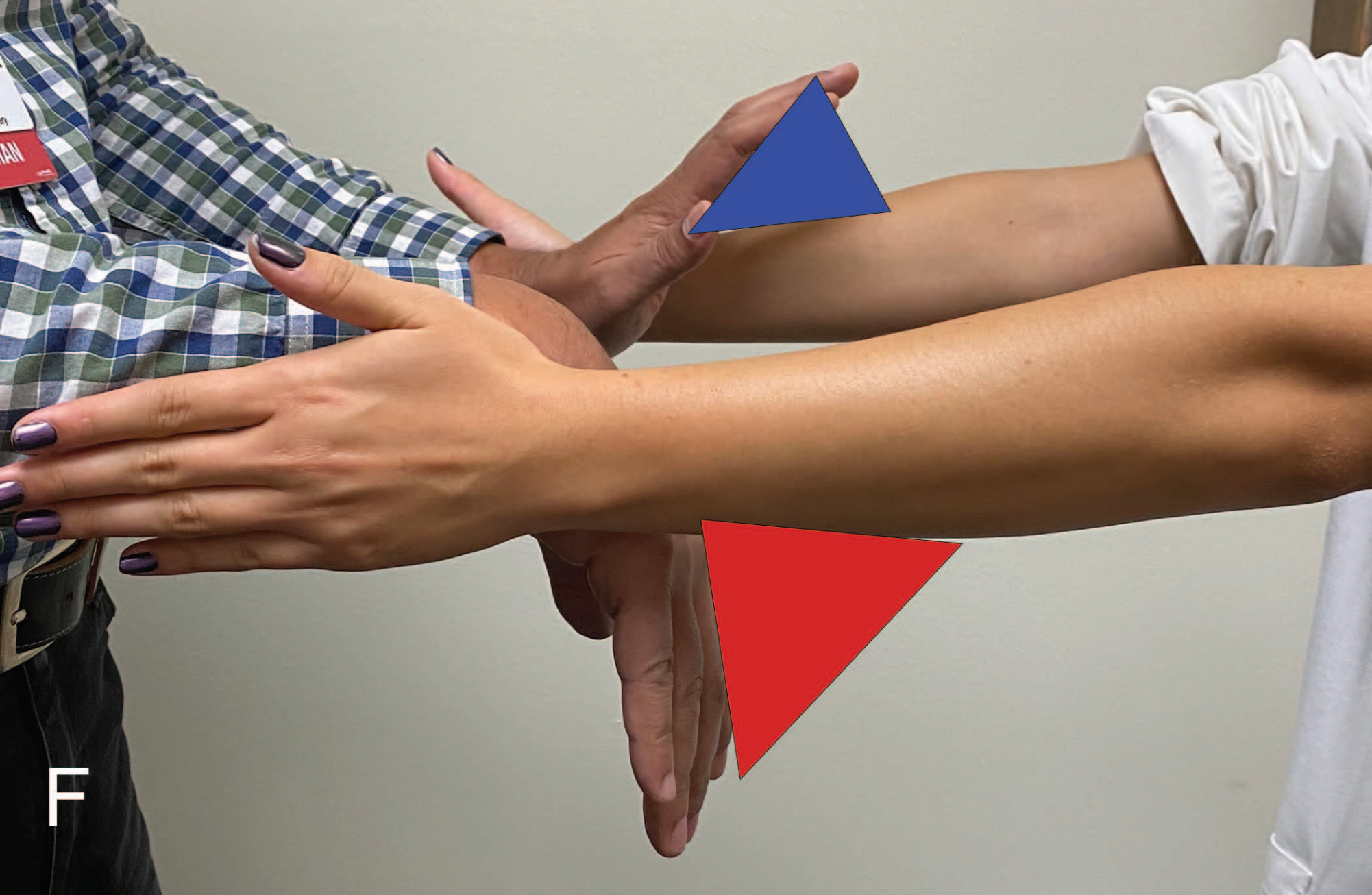

A

B


C


D


E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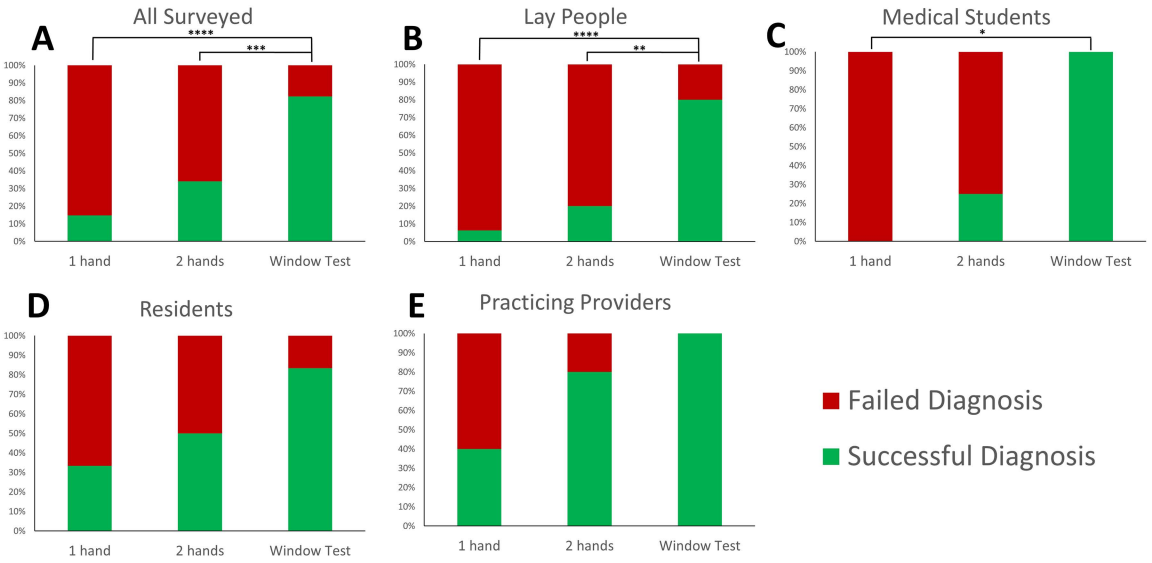
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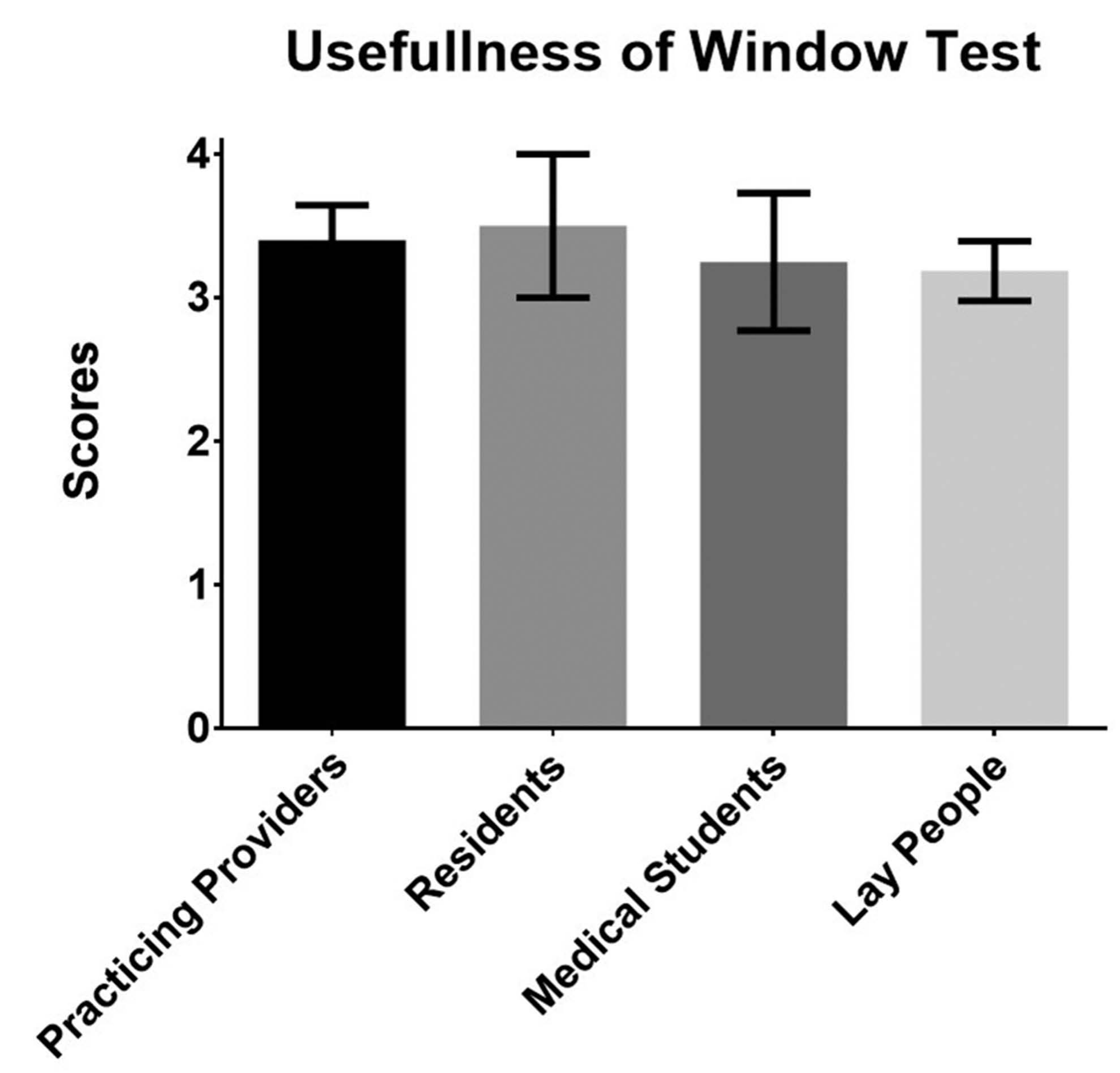
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Residents
Medical Students
Lay People


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