Original Article

The Hug-up Test: A New, Sensitive Diagnostic Test for Supraspinatus Tears

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Abstract

Background: The supraspinatus tendon is the most commonly affected tendon in rotator cuff tears. Early detection of a supraspinatus tear using an accurate physical examination is, therefore, important. However, the currently used physical tests for detecting supraspinatus tears are poor diagnostic indicators and involve a wide range of sensitivity and specificity values. Therefore, the aim of this study was to establish a new physical test for the diagnosis of supraspinatus tears and evaluate its accuracy in comparison with conventional tests.
Methods: Between November 2012 and January 2014, 200 consecutive patients undergoing shoulder arthroscopy were prospectively evaluated preoperatively. The hug-up test, empty can (EC) test, full can (FC) test, Neer impingement sign, and Hawkins-Kennedy impingement sign were used and compared statistically for their accuracy in terms of supraspinatus tears, with arthroscopic findings as the gold standard. Muscle strength was precisely quantified using an electronic digital tensiometer.
Results: The prevalence of supraspinatus tears was 76.5%. The hug-up test demonstrated the highest sensitivity (94.1%), with a low negative likelihood ratio (NLR, 0.08) and comparable specificity (76.6%) compared with the other four tests. The area under the receiver operating characteristic curve for the hug-up test was 0.854, with no statistical difference compared with the EC test ($z = 1.438$, $P = 0.075$) or the FC test ($z = 1.498$, $P = 0.067$). The hug-up test showed no statistical difference in terms of detecting different tear patterns according to the position ($\chi^2 = 0.578$, $P = 0.898$) and size (Fisher's exact test, $P > 0.999$) compared with the arthroscopic examination. The interobserver reproducibility of the hug-up test was high, with a kappa coefficient of 0.823.
Conclusions: The hug-up test can accurately detect supraspinatus tears with a high sensitivity, comparable specificity, and low NLR compared with the conventional clinical tests and could, therefore, improve the diagnosis of supraspinatus tears in clinical settings.

Key words: Hug-up Test; Physical Examination; Rotator Cuff Tear; Shoulder; Supraspinatus

Introduction

The supraspinatus tendon is the most commonly affected tendon in rotator cuff tears.[1] Early detection of a supraspinatus tear using an accurate physical examination is essential to avoiding expensive and invasive additional tests. Unfortunately, only a few physical examinations that can detect isolated lesions of the supraspinatus alone are available in the clinical setting.[2-6]

The empty can (EC) test, also known as Jobe's test or the supraspinatus test, was first described in 1982 and aimed at isolating supraspinatus activity to some degree.[7] The full can (FC) test, developed in 1996, was found to activate the supraspinatus to a level similar to that in the EC test.[8] However, these tests provided insufficient data to support the isolation of supraspinatus activity and were subsequently found to be confounded by other synergistic muscles (such as the deltoid,[5,9,10] infraspinatus,[5,11,12] subscapularis,[10,11] and serratus anterior[5,11]) on the basis of electromyographic (EMG) and biomechanical studies.[5] Furthermore, many clinical studies questioned the validity of the EC and FC tests as diagnostic tools to understand supraspinatus pathology owing to their poor to moderate specificity[2,13-16] and accuracy.[2,17,18]

The Neer sign and the Hawkins-Kennedy sign, commonly used to diagnose subacromial impingement, have a high

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sensitivity of 75–88% for supraspinatus tears.[18-21] However, these signs are characterized by a lack of specificity (<40%).[20,21] The transdeltoid palpation test, first described by Codman[22] in 1934, has been used to diagnose full-thickness rotator cuff tears and yields a high sensitivity of 82–95.7%.[23-26] However, for all types of supraspinatus tears, the sensitivity of the transdeltoid palpation test decreased to 63–67%.[23,24] Furthermore, small, nonretracted defects and partial tears with predominantly articular surface involvement are more difficult to detect with this test,[26] and it requires some experience to be utilized reliably.[23,26] Overall, the currently available commonly used physical tests for supraspinatus tears are poor diagnostic indicators with a wide range of sensitivity and specificity values. Therefore, a more accurate physical test is needed for use in a clinical setting.

Previous studies have shown that the EMG activity of the supraspinatus increased during the lift-off test, belly-press test, and bear-hug test.[27,28] Barth *et al*.[29] reported all the patients with false-positive results on the bear-hug test had a supraspinatus tear. They believed that by increasing the forward elevation of the shoulder to maximize the anterior positioning of the elbow, the supraspinatus fibers might be activated to a greater degree with the bear-hug test than with the belly-press test. On the basis of these previous studies, one would assume that recruitment and firing of the supraspinatus muscle fibers would be increased while the elbow is held as anterior as possible to the body.

Therefore, we developed a new test, the "hug-up test," wherein elevation is resisted as the palm is held on the opposite shoulder with the elbow held in maximal anterior translation. The purpose of this study was to describe the hug-up test and compare it with other conventional tests used for diagnosing supraspinatus tears. We expected a greater increase in supraspinatus activation owing to the anterior position of the elbow in comparison to the EC test and FC test, which would allow for a more sensitive detection of supraspinatus tears, especially small tears. Our hypothesis was that the hug-up test would be more accurate than other diagnostic tests for supraspinatus tears.

Methods

Herein, 200 consecutive patients scheduled to undergo an arthroscopic procedure for a diagnosis related to shoulder pain and/or weakness or dislocation by one of the senior authors from November 2012 to January 2014 were enrolled. Patients with a history of shoulder surgery, upper extremity fractures, and bilateral shoulder diseases were excluded from the study group. All patients provided informed consents. The study was carried out in accordance with the ethical standards described by the Local Ethics Committee of the National Health Commission and was approved by the Ethics Committee of Peking University Third Hospital.

The results of 5 physical tests used to detect supraspinatus tears, including the hug-up test, EC test, FC test, Neer impingement sign, and Hawkins-Kennedy impingement sign were prospectively evaluated. Pain experienced during the Neer impingement[30] and Hawkins-Kennedy impingement tests[31] and weakness during the EC test[7,14] and the FC test[8,14] were considered positive results.

All the tests were independently conducted by two authors blinded to the magnetic resonance imaging (MRI) findings for the supraspinatus. All patients were examined twice at different times. The initial tests were performed during outpatient evaluation by the senior author, and the other tests were performed on the day of admission for surgery by another trained author.

The hug-up test was performed with the patient's palm of the involved side placed on the opposite shoulder, and the elbow positioned anterior to the body [Figure 1]. The examiner then pushed the patient's elbow downward with an inferiorly directed force applied perpendicular to the elbow while asking the patient to resist the pressure [Figure 2]. The test was considered to have shown a positive result if the weakness, upon resisting the force, was >20% compared with that in the opposite side. If the strength was comparable to that of the opposite side, without any pain, the result was negative. A painful hug-up test without weakness was recorded as a separate category but was presumed to be negative.

Shoulder strength was measured for the EC test, FC test and hug-up test using an electronic digital tensiometer (GT-300, OG Giken, Japan). Resistance was applied to the wrist or elbow, perpendicular to the plane of the forearm, using a padded sling attached to the tensiometer. The patient was asked to maintain maximal resistance against the tensiometer for 5 s to obtain a static result [Figure 3].

The arthroscopic operation involved complete inspection of the supraspinatus. Supraspinatus tears were categorized as full-thickness tears (FTTs), which were classified as small (≤1 cm), moderate (≤3 cm), large (≤5 cm), and massive (>5 cm), on the basis of the largest dimension, and partial-thickness tears (PTTs), which were classified as bursal-sided, articular-sided,

Figure 1: Starting position for the hug-up test. The palm of the involved side was placed on the opposite shoulder with the elbow positioned anterior to the body.

Figure 2: The hug-up test performed using the hand. The examiner pushed the patient's elbow downward with an inferiorly directed force applied perpendicular to the elbow while asking the patient to resist the pressure.

Figure 3: The hug-up test performed with an electronic digital tensiometer. Resistance was applied to the elbow, perpendicular to the plane of the forearm, using a padded sling attached to the tensiometer. Strength was measured while asking the patient to maintain maximal resistance against the tensiometer for 5 s to obtain a static result (force was measured in Newtons).

and intra-tendinous. Other combined diseases including acromioclavicular joint derangement, infraspinatus lesions, subscapularis lesions, superior labrum anterior and posterior (SLAP) lesions, biceps disorders, and Bankart lesions were recorded as well to assess the specificity of the tests.

The accuracy of the tests was assessed by using the sensitivity, specificity, accuracy, positive predictive value (PPV), negative predictive value (NPV), positive likelihood ratio (PLR), and negative likelihood ratio (NLR), calculated from 2 × 2 tables. The reproducibility of the hug-up test was assessed with the kappa coefficient, which determined the interobserver variation. Receiver operating characteristic curve was plotted and the area under the curve (AUC) was calculated. Chi-square test or Fisher's exact test was performed to compare the sensitivity, specificity, and detection rate of the hug-up test with the arthroscopic examination conducted in different patterns, and *z*-test was used to compare the AUC of different tests. Comparisons of strength between involved and opposite sides were performed using paired *t*-tests. Comparisons of the mean difference of strength for the involved and opposite sides between patients with tears and without tears were performed using independent sample *t*-test. The level of significance was set at 0.05. The statistical analyses were performed with the SPSS 21.0 software package (SPSS Inc., Chicago, Illinois, USA).

Results

The mean age of the 200 patients was 46.8 ± 15.8 years old (range, 14–77 years old). There were 119 male and 81 female patients with 125 right and 75 left affected shoulders. The dominant side was involved in 175 cases. During the diagnostic arthroscopy procedure, we detected 153 (76.5%) cases of supraspinatus tears, including 53 combined subscapularis tears and 18 infraspinatus tears, 45 Bankart lesions, 27 SLAP lesions, 44 pathologic biceps, 3 acromioclavicular joint arthritis, and 1 Kim lesion.

The sensitivity, specificity, accuracy, PPV, NPV, PLR, NLR, and AUC for the five physical tests are listed in Table 1. The sensitivity of the hug-up test was significantly greater than that of the EC test ($\chi^2 = 7.642$, $P = 0.009$), FC test ($\chi^2 = 15.896$, $P < 0.001$), Neer impingement sign ($\chi^2 = 44.509$, $P < 0.001$), and Hawkins-Kennedy sign ($\chi^2 = 113.832$, $P < 0.001$). The specificity of the hug-up test did not significantly differ from that of the other four tests ($\chi^2 = 0.058$, $P > 0.999$, $\chi^2 = 0.254$, $P = 0.802$, $\chi^2 = 2.712$, $P = 0.169$, and $\chi^2 = 1.795$, $P = 0.284$, respectively). The AUC of the hug-up test was not significantly different from that of the EC ($z = 1.438$, $P = 0.075$) and FC tests ($z = 1.498$, $P = 0.067$), but was significantly greater than that of the Neer impingement sign ($z = 2.466$, $P = 0.007$) and Hawkins-Kennedy impingement sign ($z = 5.322$, $P < 0.001$).

The senior author reported 148 positive hug-up tests and the second examiner reported 155. The kappa coefficient for the interobserver reproducibility was 0.823 [Table 2].

The results for shoulder strength measured with the tensiometer for the hug-up test, EC test, and FC test are summarized in Table 3. The mean strength of the involved side was significantly lower than that of the opposite side in the patients with tears for the hug-up test ($t = 24.362$, $P < 0.001$), EC test ($t = 15.349$, $P < 0.001$), and FC test ($t = 14.77$, $P < 0.001$) and patients without tears for the hug-up test ($t = 3.309$, $P = 0.002$), EC test ($t = 4.086$, $P < 0.001$), and FC test ($t = 4.277$, $P < 0.001$). The mean difference in strength for the involved and opposite sides was significantly greater in patients with tears compared with those without tears for the hug-up test ($t = 12.183$, $P < 0.001$), EC test ($t = 7.592$, $P < 0.001$), and FC test ($t = 7.803$, $P < 0.001$).

The results for the hug-up test and arthroscopic examination for different tear patterns are listed in Table 4. The hug-up test showed no statistical difference in terms of detecting different tear patterns for FFTs (Fisher's exact test,

Table 1: The diagnostic values of the five tests for detecting a torn supraspinatus tendon

Items	Hug-up test	EC test	FC test	Neer impingement sign	Hawkins-Kennedy impingement sign
True-positive, *n*	144	129	120	96	55
True-negative, *n*	36	35	38	42	41
False-positive, *n*	11	12	9	5	6
False-negative, *n*	9	24	33	57	98
Sensitivity (%)	94.1*	84.3	78.4	62.7	35.9
Specificity (%)	76.6	74.5	80.9	89.4	87.2
Accuracy (%)	90	82	79	69	48
PPV (%)	92.9	91.5	93.0	95.0	90.2
NPV (%)	80.0	59.3	53.5	42.4	29.5
PLR	4.02	3.30	4.09	5.89	2.81
NLR	0.08	0.21	0.27	0.42	0.73
AUC, mean ± SE	0.854† ± 0.038	0.794 ± 0.041	0.796 ± 0.038	0.761 ± 0.037	0.616 ± 0.044

*The sensitivity of the hug-up test was significantly greater than that of the EC test ($\chi^2 = 7.642$, $P = 0.009$), FC test ($\chi^2 = 15.896$, $P<0.001$), Neer impingement sign ($\chi^2 = 44.509$, $P<0.001$), and Hawkins-Kennedy sign ($\chi^2 = 113.832$, $P<0.001$); †The AUC of the hug-up test was not significantly different from that of the EC ($z = 1.438$, $P = 0.075$) and FC tests ($z = 1.498$, $P = 0.067$), but was significantly greater than that of the Neer impingement sign ($z = 2.466$, $P = 0.007$) and Hawkins-Kennedy impingement sign ($z = 5.322$, $P<0.001$). EC: Empty can; FC: Full can; PPV: Positive predictive value; NPV: Negative predictive value; PLR: Positive likelihood ratio; NLR: Negative likelihood ratio; AUC: Area under the curve; SE: Standard error.

Table 2: Statistical analysis of the interobserver reliability of the hug-up test

Examiners	Examiner II (*n*)		
	Positive	Negative	Total
Examiner I (*n*)			
Positive	145	10	155
Negative	3	42	45
Total	148	52	200

The kappa value of cross-tabulation between examiner I and II was 0.823.

Table 3: Strength measured with a tensiometer for the hug-up test, empty can test, and full can test

Groups	Strength (N)		*t*	*P*
	Operative shoulder	Opposite shoulder		
Patients with tears (*n* = 153)				
Hug-up test	68.4 ± 39.8	123.1 ± 35.1	24.362	<0.001
EC test	40.5 ± 28.3	70.3 ± 24.0	15.349	<0.001
FC test	44.2 ± 31.9	72.5 ± 26.9	14.770	<0.001
Patients without tears (*n* = 47)				
Hug-up test	118.9 ± 32.8	128.7 ± 26.6	3.309	0.002
EC test	75.8 ± 27.3	85.7 ± 24.0	4.086	<0.001
FC test	75.5 ± 26.5	86.4 ± 25.3	4.277	<0.001

The values are expressed as means ± SD. The mean strength of the involved side was significantly lower than that of the opposite side in patients with and without tears for the hug-up test, EC test, and FC test. N: Newton; EC: Empty can; FC: Full can; SD: Standard deviation.

$P > 0.999$) and PTTs ($\chi^2 = 0.578$, $P = 0.898$) compared with arthroscopic examination.

Discussion

At present, the diagnostic accuracy of the conventional clinical tests for detecting isolated lesions of the supraspinatus remain highly variable, and a more accurate physical test for supraspinatus tears is needed in clinical practice. In our clinical practice, we developed a new test, the "hug-up test," to more accurately detect supraspinatus tears. The results of the present prospective study demonstrated that the newly proposed test can accurately detect supraspinatus tears with a high sensitivity, comparable specificity, and low NLR compared with the other 4 conventional tests mentioned above. The favorable testing profile may be useful in alerting the surgeon to a possible supraspinatus tear.

In general, a diagnostic test is considered good when the AUC is above 0.8.[32] In our study, the hug-up test yielded an AUC of 0.854, with no statistically significant difference compared with that of the EC test and the FC test in terms of diagnosing supraspinatus tears. Therefore, we can conclude that the discriminative ability of the hug-up test was at least similar to that of the conventional physical tests. Furthermore, the sensitivity of the hug-up test was higher (94.1%) than that of the conventional tests. Owing to its advantage of high sensitivity, the hug-up test could be uniquely valuable in alerting the surgeon to the specific pathology.[29] Moreover, in terms of the most important clinical measures of accuracy by far,[33,34] the PPV and NPVs of the hug-up test was very high in the 5 physical examinations, which also indicated that it is an accurate testing tool for detecting supraspinatus tears. Additionally, the specificity (76.6%) observed for the hug-up test was relatively lower than the sensitivity. Thus, we should consider the possibility of false-positive results before coming to a final diagnosis. However, the specificity of the hug-up test was acceptable in comparison with the other 4 conventional tests.

The likelihood ratios are also good summaries of diagnostic accuracy.[33,35] In the present study, the NLR of the hug-up test was the lowest (0.08) among the five tests and the PLR was high (4.02), which indicates that the accuracy of the hug-up test is not significantly influenced by the prevalence of a

Table 4: Results of the hug-up test and arthroscopic examination for different tear patterns

Items	Arthroscopic examination	Hug-up test
FTT, *n*	83	82
Small	12	12
Median	55	54
Large	4	4
Massive	12	12
PTT, *n*	70	62
Bursal-sided	39	37
Articular-sided	14	10
Intra-tendinous	17	15

FTT: Full-thickness tears; PTT: Partial-thickness tears.

disease. Moreover, the population bias was lower compared with that in the conventional tests. Thus, understanding the favorable testing profile with likelihood ratios of the hug-up test is useful to a clinician.

The reliability of a diagnostic test depends on not only the accuracy but also the reproducibility of the test results.[33] In our study, the kappa coefficient of 0.823 indicated that the hug-up test had almost perfect agreement.[35] Two factors may explain the high reproducibility. One is, in our experience, that the test is very simple to conduct and perform. The other one is the strict criterion of weakness, rather than pain, for indicating a positive result, which is relatively objective.

One may argue that the position used during the hug-up test is similar to that during Yocum's test, which is typically used for detecting tendinopathy and subacromial impingement.[36] However, the two tests are different. In Yocum's test, the patient actively elevates the arm while his or her hand is placed on the opposite shoulder. Although the position of the arm is the same as that in Yocum's test, the hug-up test requires the patient to gently elevate the arm with resistance rather than active elevation as in the Yocum's test. Moreover, the positional pain provocation caused by the possible subacromial impingement might affect muscle strength and reduce the specificity of the hug-up test. We took some measures to reduce these effects in clinical practice. Firstly, we asked the patients to elevate the arm gently and stop immediately after they experienced pain. We assumed that the painless position would avoid further impingement when muscle strength with resistance was being evaluated. Secondly, we set the positive standard as weakness, upon resisting the force, that was >20% compared with that in the opposite side. In other words, the influence of slight weakness caused by the impingement positional pain on interpreting the result as positive was expected to be as little as possible. Thirdly, pain without weakness during the hug-up test was not considered a positive result. We believe the strict criterion for interpreting the result as positive may have improved the specificity of the hug-up test as much as possible. Moreover, the position of the shoulder upon elevation and adduction during the hug-up test may also place a load on the acromioclavicular joint, which may have been the source of the pain. Because pain at the acromioclavicular joint can be easily detected by the patients and diagnosed on the basis of tenderness or plain radiography findings, we recommend that acromioclavicular conditions are ruled out when using the hug-up test to improve the specificity. However, further investigation is needed to identify the exact correlations between the hug-up test and subacromial impingement or the presence of acromioclavicular disease.

Objective strength measurement with the tensiometer showed significantly greater differences between the involved side and the opposite side in patients with tears compared with patients without tears. Diagnosing a disease according to the presence of muscle weakness is a relatively objective method. However, the advantage side with greater muscle strength may cause bias. We thus chose an electronic digital tensiometer to measure the muscle strength precisely. A result was interpreted as positive if the weakness upon resisting the force was >20% compared with that in the opposite side. We believe this criterion would allow for more objective and reliable results when determining muscle strength against resistance. However, it is not always practical to perform a physical examination with a specific device in the clinical setting. Itoi *et al*.[14] recognized both the FC and EC tests as pure manual muscle tests (MMT) and determined muscle strength by MMT using a scale of 0–5. We recommend the same method to interpret the results of the hug-up test. Muscle weakness could be defined as grade <4 using the MMT. However, it is not clear at present which MMT grade should be used to define muscle weakness. Further research is therefore needed. In the present study, we further compared the detection rate of the hug-up test with the arthroscopic examination according to the tear pattern and found no statistical differences. This indicates that the diagnostic value of the hug-up test for detecting supraspinatus tears in different positions and of different sizes was comparable to that of arthroscopic examination. However, because the number of patients with large ($n = 12$) or massive tears ($n = 4$) in our series was too small, we could not confirm whether the hug-up test was accurate for detecting larger tears. On the basis of the available literature, many classic clinical tests or signs can be used to diagnose larger tears with satisfactory sensitivity and specificity,[13,37-39] however, the diagnostic value of these tests for detecting small or partial-thickness supraspinatus tears is limited. The results of the present study may suggest the potential advantage of the hug-up test in this aspect.

The strengths of this study include its large sample size, prospective design, exact measurement of muscle strength with the tensiometer, and the reliable "gold standard" (arthroscopic examination). However, several limitations need to be considered. Firstly, the patients in the study were managed in the surgical department, and their characteristics would not be representative of the population seen in general or in medical practice. However, the shoulder lesions were confirmed using arthroscopic surgery, which is the gold standard and more reliable than any other modalities including MRI and ultrasound. In addition, we studied the accuracy of not only the hug-up test but also the conventional tests and compared them. Thus, the result is relatively reliable. Secondly, the study might have involved detection bias because one of the examiners who conducted the physical examination also conducted the surgical evaluation. We attempted to minimize this source of bias by creating a standardized protocol for the arthroscopy procedure such that all structures are investigated carefully and reported on in a standardized fashion. Thirdly, we did not include the transdeltoid palpation test for comparison in the study because its diagnostic value for all types of supraspinatus tears was reported to be limited and because it requires experience to be utilized reliably.[22-25,38] Finally, although the reliability of the hug-up test demonstrated in the present study seems to be related to the more efficient activation of the supraspinatus, EMG and biomechanical evidence is lacking and needs to be investigated in further research. However, we do agree with Somerville's and Longo's opinion in that, because of the close relationship of the structures in the shoulder, no test can selectively detect a lesion in any one of the rotator cuff tendons, and any result from muscle tests might implicate a number of structures.[6,40] What we can do is to explore a test relatively accurate for one tendon.

In conclusion, the present prospective study demonstrated that the newly proposed test, the "hug-up test," can accurately detect supraspinatus tears with a high sensitivity, comparable specificity, and low NLR compared with conventional clinical tests and might improve the diagnosis of supraspinatus tears in clinical settings. Further EMG and biomechanical investigations are necessary to analyze the supraspinatus activity when the hug-up test is performed.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Conflicts of interest

There are no conflicts of interest.

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