Quantifying shoulder rotation weakness in patients with shoulder impingement

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The purpose of this study was to determine whether strength deficits could be detected in individuals with and without shoulder impingement, all of whom had normal shoulder strength bilaterally according to grading of manual muscle testing. Strength of the internal rotators and external rotators was tested isokinetically at 60°/s and 180°/s, as well as manually with a handheld dynamometer (HHD) in 17 patients and 22 control subjects. Testing was performed with the shoulder positioned in the scapular plane and in 90° of shoulder abduction with 90° of elbow flexion (90-90). The peak torque was determined for each movement. The strength deficit between the involved and uninvolved arms (patients) and the dominant and nondominant arms (control subjects) was calculated for each subject. Comparisons were made for the scapular-plane and 90-90 positions between isokinetic and HHD testing. Despite a normal muscle grade, patients had marked weakness (28% deficit, $P < .01$*) in external rotators at the 90-90 position tested with the HHD. In contrast, external rotator weakness was not evident with isokinetic testing at the 90-90 position (60°/s and 180°/s, 0% deficit,* $P = .99$*). In control subjects, greater internal rotator strength in the dominant compared with the nondominant arm was evident with the HHD at the 90-90 position (11%,* $P < .01$*) and in the scapular plane (7%,* $P < .05$*). Using an HHD while performing manual muscle testing can quantify shoulder strength deficits that may not be apparent with isokinetic testing. By using an HHD during shoulder testing, clinicians can identify weakness that may have been presumed normal. (J Shoulder Elbow Surg 2005; 14:570-574.)*

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Muscular strength assessment provides valuable information to assist in the proper evaluation and effective treatment of a patient. Manual muscle testing (MMT) is the traditional method for the clinical assessment of muscular strength in patients with orthopaedic and neurologic pathology.[1,4,6-8,12-14,17,18,21] The criterion for a normal strength grade states that "the muscle can hold the test position against strong resistance" and "might be described as strength that is adequate for ordinary functional activities."[18] A clinician can determine that the strength score is normal; however, he or she may not be able to detect underlying subtle weakness that may exist between sides. Because MMT does not allow detection of these subtle deficits, it introduces a degree of subjectivity to the clinician's determination of possible strength deficits between involved and uninvolved limbs.[1,3,6-8,12-14,18,20,21] The identification of this subtle absolute weakness of the shoulder rotators with the shoulder in 90° of abduction and the elbow in 90° of flexion is important because it is in this position of function that the rotator cuff muscles contract to centralize the humeral head in the glenoid fossa and prevent unwanted translations and possible secondary shoulder impingement. Knowledge of side-to-side absolute weakness can provide a starting point for nonoperative rehabilitation.

The relationship between MMT scores and objective strength measurements has been thoroughly investigated.[1,3,4,6,7,10-12,24] Ellenbecker[11] compared normal-grade (5/5) manual muscle strength with isokinetic testing of the shoulder internal rotators (IRs) and external rotators (ERs). However, it may not be feasible to perform isokinetic testing during an office visit in a patient with shoulder pathology. MMT with a handheld dynamometer (HHD) may offer an alternative means of objectively determining shoulder strength.

The purpose of this study was to determine whether strength deficits could be detected in patients with shoulder impingement and control subjects without pathology, all of whom had normal shoulder strength bilaterally. MMT with an HHD was compared with isokinetic testing at 60°/s and 180°/s to detect strength deficits in impingement patients and control subjects.

MATERIALS AND METHODS

Subjects

Thirty-nine subjects volunteered to participate in this study. Group I consisted of 17 patients with shoulder impingement (13 men and 4 women). The mean height (± SD) of the patients was 167 ± 17 cm (range, 112-185 cm), the mean weight was 75 ± 12 kg (range, 54-95 kg), and the mean age was 37 ± 12 years (range, 19-63 years). Group II consisted of 22 individuals without shoulder pathology (10 male and 12 female subjects). The mean height of the control subjects was 167 ± 15 cm (range, 112-191 cm), the mean weight was 65 ± 14 kg (range, 45-100 kg), and the mean age was 21 ± 5 years (range, 14-34 years).

Instrumentation

An HHD (Nicholas Manual Muscle Test; Lafayette Instrument Co, Lafayette, IN) (Figure 1) was used to measure the peak torque of the IRs and ERs of the shoulder complex. The Biodex System 3 Multi-Joint Testing and Exercise Dynamometer (Biodex Corp, Shirley, NY) was used to perform the isokinetic peak torque strength testing of the shoulder rotators. Strength testing was performed randomly, as far as the use of the isokinetic dynamometer and HHD and the testing positions.

Inclusion criteria

The inclusion criteria for the symptomatic group included the presence of shoulder impingement confirmed by a positive Neer impingement test or a Hawkins-Kennedy impingement test (or both). The subject also had to have full passive forward elevation and no rotator cuff tear on magnetic resonance imaging or bone spurs on radiography and had to have had the condition for no longer than 12 weeks. Subjects were included if they presented with normal-grade (5/5) MMT for both the IRs and ERs of both shoulders in both the scapular-plane and 90-90 positions without pain.

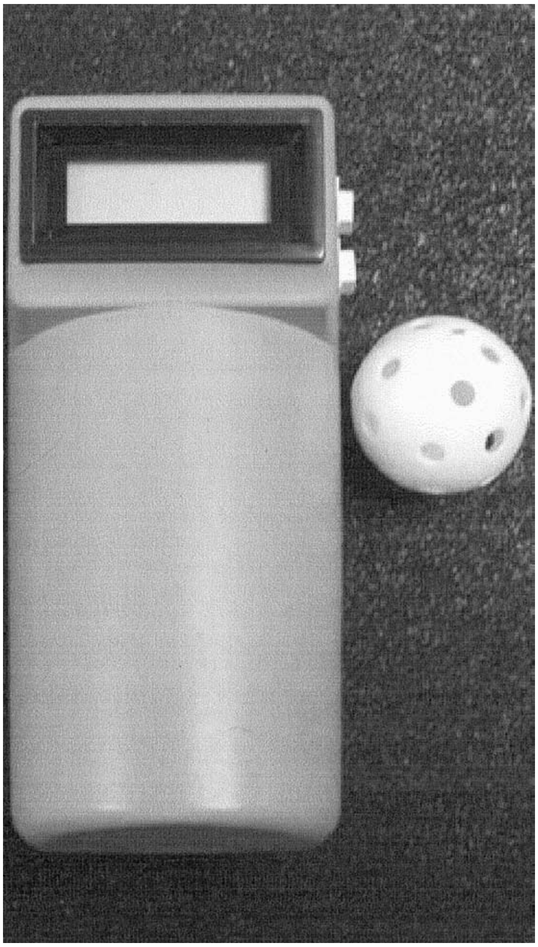

Figure 1 Photograph showing the Nicholas HHD next to a golf ball to provide perspective on the size of the device.

Testing positions

The scapular-plane position consisted of 45° of shoulder abduction, 30° of shoulder forward flexion, and 90° of elbow flexion with a neutral forearm. The 90-90 position consisted of 90° of abduction, 90° of elbow flexion, and 90° of external rotation of the shoulder. Subjects were tested in a seated position and not the traditional supine position for the testing of the IRs and ERs of the shoulder.[18] Use of the sitting position for strength assessment more specifically addresses the functional position of the upper extremity required for overhead activities than does the supine position. The same examiner performed all strength tests. Informed consent was obtained before testing, and this study was approved by our institutional review board.

Positioning procedure (isokinetic strength testing)

Subjects were tested in a seated position randomly in both the scapular-plane and 90-90 positions. They were positioned in the Biodex 3 according to Leroux et al[19] for the scapular-plane position and according to the recommendations in the Biodex 3 handbook for testing: 90° of shoulder abduction, 90° of elbow flexion, and 90° of external rotation in the sitting position. The sitting position was used to replicate the original testing position for MMT.

Positioning procedure (handheld dynamometry)

Subjects were tested sitting on the Biodex chair in both the scapular-plane and 90-90 positions. For the ER measurements, the examiner stabilized the medial aspect of the distal humerus with the nontesting hand, and the HHD was centered on the dorsal aspect of the distal forearm. For the IR measurements, the examiner stabilized the lateral aspect of the distal humerus, and the HHD was centered on the volar aspect of the distal forearm. A towel roll was placed in the axillary region for testing in the scapular plane.

Isokinetic strength testing

An explanation of the testing procedure was given to all subjects before the onset of testing, with emphasis on exerting maximal effort within the subjects' tolerance. All subjects were fully compliant and pain-free during testing. Isokinetic strength testing was performed at 60°/s and

Table I Mean values (± SE) of peak torque of shoulder IRs and ERs at 60°/s and 180°/s for scapular plane and 90-90 positions in patients and control subjects

	Scapular plane				90-90 Position			
	60°/s		180°/s		60°/s		180°/s	
	IR	ER	IR	ER	IR	ER	IR	ER
Control subjects								
Dominant arm (Nm)	29.0 ± 2.6	24.5 ± 2.0	24.9 ± 2.3	18.5 ± 1.3	30.4 ± 2.8	25.2 ± 2.7	25.8 ± 2.4	20.6 ± 2.2
Nondominant arm (Nm)	29.8± 2.8	25.2 ± 1.9	27.1 ± 2.7	20.1 ± 1.7	32.8 ± 3.1	25.9 ± 2.9	28.5 ± 2.7	21.0 ± 2.2
% Deficit	2.31	2.48	6.18	4.36	4.34	–0.27	6.99	0.07
P value	.99	.99	.74	.99	.99	.99	.29	.99
Patients								
Involved arm (Nm)	34.9± 3.8	24.3 ± 3.0	33.9 ± 3.6	21.7 ± 2.5	37.1 ± 4.3	25.6 ± 3.3	35.7 ± 4.2	22.0 ± 3.1
Uninvolved arm (Nm)	37.5 ± 3.9	28.1 ± 3.4	36.7 ± 4.0	23.5 ± 2.8	41.2 ± 5.1	28.5 ± 3.2	37.6 ± 4.9	24.4 ± 2.7
% Deficit	7.15	13.16	6.76	6.12	7.20	8.80	1.48	11.66
P value	.41	.07	.54	.99	.33	.61	.99	.38

180°/s. The peak torque during 5 repetitions at 60°/s and 15 repetitions at 180°/s was recorded. Peak torque was defined as the maximum torque produced by the shoulder at any point in the range of motion (in Newton-meters). The 60°/s speed was first performed for each extremity, followed by the 180°/s speed. Testing was performed by use of a range of motion of 0° to 90° for the 90-90 and scapular-plane positions. The test was initiated with the arm in 90° of external rotation. Two trial repetitions at each speed were performed to prepare the subject for the testing procedure. A 30-second resting break was allowed for each subject between testing speeds. Standardized verbal instructions and encouragement were given to all subjects. Visual biofeedback of torque production was not provided during the isokinetic testing procedure.

Handheld dynamometry strength testing

An explanation of the testing procedure was given to all subjects before the onset of testing, with emphasis on exerting maximal effort within the subjects' tolerance. The examiner used the break test for the strength measurements of the shoulder rotators in both the scapular-plane and 90-90 positions.[22] The subject was asked to hold the position of the extremity as the examiner pushed against the subject's limb until the maximal muscular effort was overcome and the joint being tested gave way.[22] Force measurements from the HHD were converted to joint torque by multiplying the values by the length of the lever arm. The lever arm was measured from the lateral epicondyle to the ulnar styloid process. Standardized verbal instructions and encouragement were given to all subjects during the testing procedure.

Data analysis

The strength deficit between the involved and noninvolved arms (patients) and the dominant and nondominant arms (control subjects) was calculated for each subject. One-sample *t* tests were used to determine whether significant side-to-side differences were present for the isokinetic and HHD tests in each of the test positions. Because 3 deficits are reported for each test position (60°/s, 180°/s, and HHD), the level of significance was adjusted appropriately. All *P* values reported in the tables have been multiplied by 3 such that the threshold for statistical significance of $P < .05$ reflects a value of $P < .016$.

RESULTS

Mean peak torque isokinetic values of the shoulder rotators at 60°/s and 180°/s for both testing positions are shown in Table I. Significant weakness was not evident with isokinetic testing for either position or speed tested. Mean values for peak torque of the shoulder rotators as measured by HHD for both the scapular-plane and 90-90 positions are shown in Table II. Testing with the HHD revealed significant weakness in ERs in both the 90-90 position (28% deficit, $P < .01$) and the scapular-plane position (11% deficit, $P = .02$) in patients. A dominance effect in IR strength was detected in the scapular-plane position (11% deficit, $P < .01$) and in the 90-90 position (7% deficit, $P = .03$) in control subjects (Table II). HHD was able to identify clinically significant deficits (>15% compared with uninvolved arm) in ERs in the 90-90 position in 14 of 16 patients. In contrast to HHD, 7 of 16 patients tested isokinetically in external rotation at 60°/s in the 90-90 position ($P = .046$) and 6 of 16 patients at 180°/s in the 90-90 position ($P = .018$) had clinically significant deficits.

DISCUSSION

The HHD appeared to be more sensitive in detecting shoulder external rotation strength deficits in patients compared with isokinetic testing. In addition, in

Table II Mean values (± SE) of peak torque of shoulder IRs and ERs with HHD for scapular- plane and 90-90 positions in patients and control subjects

	Scapular plane		90-90 Position	
	IR	ER	IR	ER
Control subjects				
Dominant side (Nm)	48.3 ± 3.8	32.8 ± 2.7	36.1 ± 3.0	30.1 ± 2.6
Nondominant side (Nm)	42.5 ± 3.3	31.3 ± 2.2	33.1 ± 2.5	30.2 ± 2.5
% Deficit	10.74*	1.71	6.55*	–4.18
P value	<.01	.99	.03	.98
Patients				
Involved side (Nm)	47.3± 4.7	34.2 ± 3.8	39.3 ± 4.7	27.2 ± 3.7
Uninvolved side (Nm)	49.4 ± 5.2	38.8 ± 4.0	45.7 ± 4.6	37.5 ± 3.7
% Deficit	2.35	11.07*	10.51	28.16*
P value	.99	.02	.47	.01

*Statistically significant difference ($P < .05$).

patients with shoulder impingement, the 90-90 position may be more sensitive in detecting strength deficits compared with the scapular plane. This is not the first study to detect strength deficits when shoulder strength was presumed normal by use of traditional MMT.[11] Ellenbecker[11] showed significant differences between extremities in isokinetic peak torque and single-repetition work scores of the shoulder rotators tested isokinetically at 210°/s and 300°/s. One hundred fourteen consecutive subjects were tested isokinetically in internal rotation and external rotation at 210°/s and 300°/s. Results identified significant ($P <$ .01) side-to-side differences between extremities in isokinetic peak torque and single-repetition work scores. Percent differences ranged from 13% to 17% in the study population and 11% to 28% in the control group, both with a normal grade (MMT). This study demonstrated that individuals with bilateral normal-grade shoulder rotator strength as measured by MMT may have clinically significant side-to-side deficits measured isokinetically. Similarly, in our study strength deficits were apparent where traditional MMT did not detect weakness. A possible explanation for the significant external rotation deficit identified with the HHD, but not with isokinetic testing, could be that isokinetic testing typically reports peak torque, which occurs at the middle of the range of motion. Strength may be adequate at mid range, but a deficit may be present at the end range of motion. This may be a possible explanation for the significant external rotation deficit identified with the HHD but not with isokinetic testing, as muscle testing with the HHD was tested at end range. Clinically, the end of the range of motion is a possible position of impingement, where the shoulder rotators might require more absolute force with less mechanical advantage to provide adequate dynamic stability to prevent secondary impingement. In fact, strength may be adequate at mid range, but a deficit may be present at the end range of motion. It is important for the clinician to use more objective measurements, such as an HHD, because traditional MMT is unable to detect side-to-side differences in symptomatic subjects. The ability to identify this absolute strength deficit and address the weakness with therapeutic exercise may be important in decreasing symptoms in this patient population.

The reliability of tests for isometric strength of the shoulder joint has been established in patients with shoulder pathology. Hayes et al[15] compared 3 different methods of strength testing: traditional MMT, HHD, and a spring-scale dynamometer. The results demonstrated that the HHD was the most reliable for assessing strength of the rotator cuff in symptomatic subjects. Rabin and Post[21] studied 100 consecutive patients treated with shoulder surgery to determine their functional recovery by comparing MMT and isokinetic evaluation. Clinical grading of muscle strength was compared preoperatively and postoperatively with the Cybex II Isokinetic System (Cybex, Ronkonkoma, NY). MMT scores increased postoperatively by approximately one half of a grade in both forward flexion and external rotation. Isokinetic parameters did not significantly improve. Only weak statistical correlations were found between the clinical muscle grading and the isokinetic dynamometer.

In addition to the external rotation deficits measured by the HHD, the effect of dominance was also evident in internal rotation as tested with the HHD in the scapular-plane (11% deficit) and 90-90 positions (7% deficit) in the control subjects. A dominance effect was not apparent with isokinetic testing at either speed or position. Warner et al[23] reported that isokinetic testing of asymptomatic subjects demonstrated an internal rotation dominance effect at 90°/s and 180°/s in a modified abducted position. Hinton[16] found an internal rotation dominance effect in high school pitchers without significant differences in ER strength. In contrast, Alderink and Kuck[2] did not find significant differences in internal rotation strength between nondominant and dominant shoulders of high school and college baseball pitchers, but a significant deficit in ER strength was found on the nondominant side.

Unfortunately, objective strength-testing methods, such as isokinetic testing and HHD, have limitations. Clinically, the isokinetic dynamometer is expensive, presents a high cost to the patient, requires a large amount of space, and involves time-consuming testing sessions.[9] In addition, the HHD measurement is dependent, in part, on the strength of the clinician holding the dynamometer and the ability to hold the dynamometer steady and perpendicular to the limb segment being tested.[5] A potential limitation to this study was whether a maximum effort was given by all subjects. Because the patients included in this investigation presented with impingement syndrome of the shoulder, apprehension may have limited their ability to provide maximum effort during both strength-testing methods. Furthermore, we designed the study to examine the side-to-side differences within subjects, and it must be recognized that the groups were not matched for age and gender, making absolute comparisons a limitation of this study.

Because the HHD has been shown to have excellent interrater reliability (ρ = 0.79-0.92) for all movements of the shoulder and excellent intrarater reliability (ρ = 0.79-0.96) for elevation, external rotation, and internal rotation, our study indicates that the HHD is another viable option for measuring the strength of the shoulder rotators.[15] By using an HHD during shoulder testing, clinicians can identify weakness that might have been presumed normal. Strength deficits can be detected with an HHD while performing MMT that were not apparent during isokinetic testing. Therefore, when testing shoulder external rotation strength, the patient with suspected shoulder impingement should be placed in the 90-90 position to reveal maximum weakness of the shoulder ERs. Therefore, HHD should be used as an efficient and effective means by which to measure strength objectively in patients with suspected shoulder impingement.

The Nicholas HHD was developed at our institute in the 1970s by James A. Nicholas, MD, but is now called the Lafayette HHD because the patent has expired. Our institute does not receive royalties from this product nor do we have an association with the current manufacturer, Lafayette Instrument Co.

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