Technical and measurement report

Anatomical validity of the Hawkins–Kennedy test — A pilot study

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Purpose: Despite routine use, clinical tests used to diagnose subacromial impingement often display poor diagnostic accuracy. A lack of anatomical validity may contribute to the poor diagnostic accuracy. The current study aimed to examine the anatomical validity of measuring subacromial pressure in the Hawkins–Kennedy impingement test in a cadaveric shoulder.

Methods: Subacromial pressures were measured using pressure transducers in non-provocative and provocative Hawkins–Kennedy test positions using an ABA research design with 25 repeated measures in one cadaver. Data collected included pressure at four subacromial locations (coracoid process, coraco-acromial ligament, anterior acromion and posterior acromion), and observation of anatomical structures impinging on transducers. The split-middle method of visual analysis and the Reliable Change Index (RCI) were applied to examine any differences between provocative and non-provocative positions.

Results: There was increased pressure in the provocative position at the coraco-acromial ligament, which impinged biceps brachii, and at the anterior acromion, which impinged the rotator interval.

Conclusion: Findings of the current study provide evidence that suggest that structures other than the rotator cuff tendons may be impinged during the Hawkins–Kennedy test.

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1. Introduction

Shoulder pain is common with a point prevalence in the general community of 14–21% (Bongers, 2001; Picavet and Schouten, 2003). Approximately 40% of all patients who visit a doctor for shoulder pain are diagnosed with impingement syndrome (Van der Windt et al., 1995). Impingement syndrome is used to describe the patho-mechanics of increased subacromial compression of the rotator cuff, subacromial bursa and biceps tendon during arm elevation (Neer, 1983; Wuelker et al., 1994).

The Hawkins–Kennedy clinical test is routinely used to detect subacromial impingement by placing the shoulder joint in a position that increases contact between the head of humerus and acromion, therefore compressing structures that course through the subacromial space (Roberts et al., 2002). The test developers proposed that during their test the supraspinatus tendon is compressed against the under surface of the coraco-acromial ligament (Hawkins and Kennedy, 1980). A positive test is reproduction of pain. Although this clinical test to determine impingement is commonly used, the diagnostic accuracy is often poor (Hegedus et al., 2007; Hughes et al., 2008).

A lack of anatomical validity to support the use of this clinical test may explain the poor diagnostic accuracy (Green et al., 2008). Evidence of anatomical validity of shoulder impingement can be established by measuring subacromial pressure during clinical tests to determine if the test increases compression on the structure that it purports to place stress on.

Therefore the main aim of the current study was to compare the subacromial pressure between provocative Hawkins–Kennedy shoulder impingement test position and a non-provocative position using pressure transducers in a cadaveric upper limb. It was hypothesised that the pressure would be significantly higher in the provocative position therefore providing evidence about the anatomical validity of the Hawkins–Kennedy test.

2. Methods

2.1. Design

We used a single-case ABA research design to determine whether there was a significant difference in subacromial pressure between a non-provocative position and the Hawkins–Kennedy impingement test position in one cadaver specimen.
2.2. Apparatus

Single use force sensitive resistors (model No. 400 Interlink Electronics, California, Fig. 1) were used as the transducers to measure subacromial pressures. The pressure transducers were sufficiently small (5 mm diameter) to be placed in the subacromial arch and were affordable (less than AUD55 for each transducer).

The electrical output from the pressure transducers was connected to an existing 4-channel PowerLab unit via a custom designed 4-channel variable offset amplifier (Computing and Technical Services Unit, Faculty of Health Sciences) with a maximal error due to noise of 1.2%. The data were then fed directly to a computer and collected using LabChart 6 for Windows' software (ADI Instruments, Sydney). Data were collected at a frequency of 1000 Hz. For each trial the mean pressure data was obtained for a 200 ms period commencing from the time the limb was placed in the required position.

The inter-device reliability of the pressure transducers was determined in a bench top experiment. Four pressure transducers were tested by applying a series of 10 weights (31–91 g) to each transducer in 6 g intervals across 5 trials. There was high inter-device reliability in each of the 5 trials (Intraclass Correlation Coefficient ICC [3,1] = 0.96, 0.92, 0.88, 0.97 and 0.98).

Subacromial pressure measurements with the transducers in Hawkins–Kennedy impingement test position displayed high re-test reliability (ICC [2,1] = 0.88, 95% confidence interval [CI] 0.61–0.99) across five trials using pressure transducers in four subacromial locations.

![Fig. 1. Supero-lateral view of left cadaveric upper limb with borders of rotator cuff tendons traced onto the glenohumeral joint capsule and pressure transducers attached (CP = coraco-acromial ligament, AA = anterior acromion, PA = posterior acromion, RI = rotator interval, SS = supraspinatus tendon, IS = infraspinatus tendon, TM = teres minor tendon, pressure transducer fixed under AA). Note that subscapularis tendon is anterior to RI (not fully visible on this figure).](image)

2.3. Procedure

Dissection of one cadaveric upper limb complete with pectoral girdle involved removal of the deltoid muscle and subacromial bursa to expose the glenohumeral joint capsule and the rotator cuff tendons. The embalmed cadaver specimen was an 82 year old male with no observed pathology of rotator cuff tendons nor previous surgery. The body of the scapula was fixed in a vice using two bolts so that the limb was suspended in the anatomical position with the glenohumeral joint free to move. The borders of the exposed muscle fibres of subscapularis, supraspinatus, infraspinatus and teres minor tendons were traced laterally, representing the blending of the tendon of each muscle onto the exposed joint capsule using a permanent marker. The rotator interval was marked between subscapularis and supraspinatus tendons (Fig. 1).

The four pressure transducers were adhered to the specimen in the following positions within the subacromial space (Fig. 1):

- posterior surface of coracoid process
- mid-point of the coraco-acromial ligament
- 1 cm posterior to the anterior border of the lateral edge of the acromion process
- 1 cm anterior to the posterior border of the lateral edge of the acromion process.

Shoulder flexion angle in each test position was measured using a universal goniometer (model G300; Whitehall Manufacturing, City of Industry, CA). Universal goniometers have demonstrated excellent re-test reliability in measuring shoulder flexion (ICC: 0.91–0.97) with high levels of agreement with digital inclinometers (ICC: 0.81–0.95) (Mullaney et al., 2010). The Hawkins–Kennedy test position was performed by passively flexing the glenohumeral joint to 60° and adding maximal internal rotation to a point where the tissues were providing significant passive resistance. The non-provocative position was 60° passive shoulder flexion without any shoulder rotation. According to the two-to-one ratio of scapulo-humeral rhythm described by Levangie and Norkin (2005), when the shoulder is at 90° flexion the glenohumeral joint contributes 60° and the scapula-thoracic joint contributes 30°. Recent three-dimensional studies confirm that the scapula-thoracic joint contributes between 20° and 40° of the first 90° of elevation (McClure et al., 2001; Yano et al., 2010). As the scapula of the cadaver was fixed in the vice this normal two-to-one ratio was disrupted. Therefore for this study, 60° of glenohumeral flexion in the cadaver was approximately equivalent to 90° shoulder flexion in a living person.

As part of the ABA research design in phase A, the non-provocative position was repeated for 10 consecutive trials. The provocative test position was then completed for 10 consecutive trials in phase B. Testing was then repeated in phase A, the non-provocative position for another five consecutive trials. The limb was returned to the neutral (anatomical) position between each trial. Tests were performed in series with approximately 1 min intervals between each trial. The person carrying out the movement of the cadaver specimen was blinded to the pressure being recorded.

2.4. Data analysis

Two methods of analysis for single subject data were used to increase the strength and confidence of findings: Reliable Change Index (RCI) and visual analysis using the split-middle method of trend estimation. A difference between the provocative and non-provocative positions was only considered significant if indicated by both analyses.
The RCI tests whether two or more scores obtained from the same subject on two or more occasions are significantly different and is based on the rationale that difference in the scores on the two different occasions (non-provocative position versus provocative position) should be much greater than the variability due to measurement error (Gorman and Allison, 1997). The RCI is suitable for use on small data series and can assess changes beyond those resulting from measurement error (Harbst et al., 1991).

The RCI results in a z score. For this experiment a Bonferroni correction, that divides the significance level by the number of comparisons, was performed to decrease the risk of a type one error. Allowing for eight comparisons in the current study a z score of >2.75 was accepted as significant at the 0.006 (0.05/8) level (Portney and Watkins, 2000, p461). The RCI was calculated for both phase A–B and B–A for each subacromial transducer location.

Data obtained in the non-provocative and provocative test positions were graphed. The split-middle method of trend estimation was applied to the graphed data (Nourbakhsh and Ottenbacher, 1994). This method is designed to demonstrate whether data are displaying a change in level or trend between the non-provocative (A) and provocative (B) positions. To do this, a line of best fit or ‘celeration line’ was applied to the non-provocative position; the line was extended to data in the provocative position. The difference between the non-provocative and provocative test positions was assessed by comparing the proportion of points above and below the celeration line across the two test positions. Statistical significance was determined using a binomial test with an alpha level of 0.006 accepted as the level of significance allowing for the eight comparisons. If there is no difference between the two positions the proportion of data points above and below the line should remain the same between the test positions (Nourbakhsh and Ottenbacher, 1994).

Subacromial pressure values were expressed as grams. Data obtained via observation of the cadaver were recorded and tabulated to analyse if pressure transducers were in contact with the specimen and, if so, which tendon was in contact with the transducer.

### 3. Results

There was a statistically significant difference in subacromial pressure between the non-provocative and provocative positions for both phase A–B and B–A for transducers at the coracoid process, coraco-acromial ligament, and at the anterior acromion, but not at the posterior acromion. The average range of shoulder internal rotation measured during the five trials was 50° (range: 45–52°). There was a large increase in pressure in the provocative position for transducers placed at the coraco-acromial ligament, and the anterior acromion (mean increase of 43 g (95% CI 36–50 g) and 23 g (95% CI 15–32 g) respectively, Table 1, Fig. 2). The transducer placed at the coracoid process demonstrated a small decrease in pressure of 6 g (95% CI 3–9 g) in the provocative position and there was no change in the pressure at the transducer at the posterior acromion (mean increase <0.1 g, 95% CI 0.01–0.20 g).

On observation, long head of biceps brachii tendon was impinged in the intertubercular groove by the coraco-acromial ligament and the coracoid process, and the rotator interval was impinged by the anterior acromion during the provocative test positions (Table 1).

### 4. Discussion

Subacromial impingement is a common cause of shoulder pain. Hawkins and Kennedy (1980) proposed that during their test the supraspinatus tendon is impaled against the under surface of the coraco-acromial ligament. Supraspinatus is most commonly implicated in impingement syndrome closely followed by infraspinatus. Pathology of subscapularis usually occurs in conjunction with other rotator cuff findings and teres minor pathology is uncommon (Chung et al., 2008).

However, in our study Hawkins–Kennedy impingement test did not compress supraspinatus within the subacromial space and this is consistent with another recent study replicating this test using cadaver specimens (Yamamoto et al., 2009). The only structures observed to be compressed in the provocative test position were the long head of biceps brachii tendon and the rotator interval, structures which are rarely implicated in impingement syndrome. Yamamoto et al. (2009) indicated contact between the subscapularis tendon and both the coraco-acromial ligament and the acromion process in the Hawkins–Kennedy position (Yamamoto

![Fig. 2. Graphical representation and celeration line for pressure transducer 2 (coraco-acromial ligament) subacromial pressures (g) during non-provocative (A) and provocative (B) positions.](image-url)

### Table 1

<table>
<thead>
<tr>
<th>Pressure transducer</th>
<th>Trial</th>
<th>RCI (z)</th>
<th>Binomial test (p)</th>
<th>Muscle/tendon in contact with pressure transducer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Coraco process</td>
<td>A–B</td>
<td>−4.1*</td>
<td>0.002*</td>
<td>Yes</td>
</tr>
<tr>
<td>2. Coraco-acromial ligament</td>
<td>A–B</td>
<td>219.4*</td>
<td>0.002*</td>
<td>Biceps brachii long head</td>
</tr>
<tr>
<td>3. Anterior acromion</td>
<td>A–B</td>
<td>10.7*</td>
<td>0.002*</td>
<td>Yes</td>
</tr>
<tr>
<td>4. Posterior acromion</td>
<td>A–B</td>
<td>2.9*</td>
<td>0.34</td>
<td>No</td>
</tr>
</tbody>
</table>

* Statistically significant change \( p \leq 0.006. \)
et al., 2009). Although subscapularis was not impinged in the current study, the adjacent nature of subscapularis tendon on the lesser tuberosity and the long head of biceps tendon in the inter-tubercular groove indicate that Yamamoto’s findings are similar findings to the current study. These results raise the possibility that production of pain during the Hawkins–Kennedy test may be due to compression of structures other than the supraspinatus tendon.

The presence of neuropeptides consistent with pain sensation has been recently confirmed in the long head of biceps tendon thus confirming this structure as a possible source of shoulder pain (Alpantaki et al., 2005). The result of the current study may also help to explain the relatively poor accuracy of Hawkins–Kennedy test in diagnosing rotator cuff pathology (Hughes et al., 2008).

Our results are also consistent with other observations that have not been able to demonstrate supraspinatus contact with the acromion or coraco-acromial ligament during the Hawkins–Kennedy test (Roberts et al., 2002; Struhl, 2002). However, Pappas et al. (2006) observed subacromial contact of the supraspinatus or infraspinatus in their magnetic resonance imaging (MRI) investigation, while Valadie et al. (2000) observed that the coraco-acromial ligament was in contact with rotator cuff tendons or biceps tendon in four cadaveric specimens during the test although it was not stated if supraspinatus tendon was implicated. Our results add to the previous literature by basing our conclusions on direct measurement of pressure and not just observation.

One potential limitation of our study is that the measurement error in the pressure transducer may have obscured any real differences between the provocative and non-provocative positions of the Hawkins–Kennedy test. However, we established that the device demonstrated high levels of inter-device and re-test reliability. This suggests that the pressure transducer had sufficient reliability to overcome measurement error and detect large increases in subacromial pressure in the provocative positions during Hawkins–Kennedy test position.

A further limitation is that the results of this study are based on a single cadaver. To partly account for this we used a rigorous single-case design analysis. Finally, a limitation is that the subacromial bursa, a common source of pain in impingement syndrome (Lewis, 2009), was removed from the cadaver during dissection. However, our procedure allowed us to test whether the supraspinatus tendon is compressed against the under surface of the coraco-acromial ligament as proposed by the test developers (Hawkins and Kennedy, 1980).

5. Conclusion

Findings of the current study provide evidence of the anatomical validity of Hawkins–Kennedy test, and provide new evidence that suggest that structures other than the rotator cuff tendons may be impinged during this test.

Acknowledgements

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References


