# Does subscapularis splitting technique during the Latarjet procedure matter? Muscle moment arms and lines of action in a cadaveric model

Aaron S. Fox[*,a,b], Richard S. Page[b,c,d], Janina Henze[1], Lukas Ernstbrunner[e], David C. Ackland[f]

[a] *Centre for Sports Research, School of Exercise and Nutrition Sciences, Deakin University, Geelong, Australia*
[b] *Barwon Centre for Orthopaedic Research and Education (B-CORE), Barwon Health, St John of Jod Hospital and Deakin University, Geelong, Australia*
[c] *School of Medicine, Deakin University, Geelong, Australia*
[d] *Orthopaedic Department, University Hospital Geelong, Barwon Health, Geelong, Australia*
[e] *Department of Orthopaedic Surgery, University Hospital Balgrist, Zurich, Switzerland*
[f] *Department of Biomedical Engineering, University of Melbourne, Parkville, Australia*

**Abstract**

TODO: Add abstract…

## 1. Introduction

***TODO: copy across a lot of this to multiple split paper…***

Shoulder instability injuries occur with excessive force that translates the humeral head out of the glenohumeral joint socket (**Thangarajah2016?**), and are a concerning problem affecting young athletes in overhead collision sports (e.g. Australian football, rugby) (**Orchard2013?**). Effective clinical care is vital to avoid recurrent injuries, as well as reduced shoulder function and joint degradation (**Thangarajah2016?**). Surgery is often needed to address pathology, restore function and correct stability (**Kavaja2012?**). The Latarjet procedure is a non-anatomic, open shoulder reconstruction involving a bone block via transfer of the coracoid process to the anterior glenoid with the attached conjoint tendon (**Latarjet1954?**). The Latarjet procedure is commonly used in cases with significant glenoid bone loss, large humerus compression fractures, or glenoid and humeral bone defects (**Millett2005?**) — and is effective in combatting recurrent anterior instability injury (**Bessiere2014?**). Latarjet procedures are also emerging as the preferred option for surgical shoulder stabilisation, especially in contact sport settings (**Bonazza2017?**).

The Latarjet procedure requires high precision, and subtle variations in surgical technique may impact the likelihood of degenerative changes and subsequent injury (**Ghodadra2010?**). An important choice in the Latarjet procedure is the treatment of the subscapularis muscle (**Bhatia2014?**). The subscapularis muscle must be manipulated to access the anterior portion of the glenohumeral joint and place the coracoid bone graft. Early iterations of the Latarjet procedure completely dissected the subscapularis tendon and reflected the muscle to expose the anterior joint capsule. Complete release of the subscapularis during surgery can elevate the risk of future tears to the tendon (**Lazarus2000?**). Further, the subscapularis is a strong anterior stabiliser of the joint (**Lee2000?**) and therefore maintaining its integrity is relevant to joint stability. Subsequently, the current recommended approach (**Bhatia2014?**) is to use a horizontal split through the muscle fibres (i.e. a subscapularis split). Using the subscapularis split approach, the final position of the conjoint tendon passes through the split, adding tension to the inferior portion in extreme degrees of abduction and/or external rotation (**Yamamoto2013?**). This added tension in the subscapularis enhances anterior and inferior joint stability (**Yamamoto2013?**).

Although a subscapularis splitting approach for the Latarjet procedure is advocated, variable techniques for the location of the split are reported (**Shah2012?**). This includes splitting the subscapularis at: (i) the junction of its superior and middle thirds (i.e. one-third from the top) (**Burkhart2007?**); (ii) the junction of its upper two-thirds and lower one-third (i.e. one-third from the bottom) (**Shah2012?**); or (iii) along the fibres at the 'middle third' (i.e. mid-point of the muscle) (**Allain1998?**). Understanding which split location optimises stability and function is key for providing further guidance around the Latarjet procedure. However, the effect on stability and muscle function for varying split locations has not been

*Corresponding Author: aaron.f@deakin.edu.au

extensively tested. Of those studies which have investigated the stabilising mechanisms of the Latarjet procedure (**Wellmann2012?**) — the majority have used a split at the upper two and lower one-thirds of the muscle (**Wellmann2012?**); while one did not report the location (**Giles2013?**). There is a clear gap in understanding how variable subscapularis split locations furing the Latarjet procedure impacts its mechanical stabilising effect. Further, none of the aforemention mechanistic studies (**Wellmann2012?**) have examined muscle anatomy and function. The Latarjet procedure and splitting technique used will have a substantial effect on subscapularis muscle moment arms and lines of action. The moment arm of a muscle largely determines its role as a stabiliser and prime mover (**Ackland2008?**). A muscle's line of action dictates the direction in which it produces force (**Ackland2009?**). Muscles whose line of action produces predominantly compressive forces stabilise the shoulder, while those that produce predominantly shear forces may help cause instability (**Ackland2003?**). Understanding how subscapularis splitting alters the moment arms and lines of action of the subscapularis can reveal further information about this muscles contribution to shoulder joint stability folowing the Latarjet procedure. Assessing the various splitting techniques may also provide support for an optimal method.

This study examines how varying subscapularis splitting techniques within the Latarjet procedure impacts subscapularis muscle function and the potential for shoulder joint (in)stability. First, the moment arms and lines of action of subscapularis muscle sub-regions across various glenohumeral joint positions under different subscapularis splitting techniques are examined. Second, these data are used to assess the potential contributions of the subscapularis muscle sub-regions to glenohumeral joint stability under the different subscapularis splitting techniques.

## 2. Methods

### *2.1. Specimen Preparation*

***XXXXX*** (***X male, X female; . . . enter participant details***) fresh-frozen, entire upper extremities were obtained from human cadavera. Ethics approval for the use of specimen in this study was obtained from the ***Health Sciences Human Ethics Sub-Committee, University of Melbourne***. All specimens were arthroscopically screened to ensure they were free of degenerative changes such as osteoarthritis, rotator cuff tears and significant joint contracture. Specimens were thawed at room temperature 24 hours prior to dissecting and testing.

**TODO: add details about specimen preparation. . .**

**TODO: include details from Janina re: Latarjet procedures. . .**

### *2.2. Experimental Protocol*

***. . .***

Nylon lines were attached to the suture of each proximal tendon of the subscapularis regions and passed through a perforate plate to a free hanging weight of ***. . . insert load. . .***. This maintained muscle-tendon unit tension while minimising load induced muscle-tendon lengthening, and assisted in producing joint congruency during testing. Each tendon unit was pulled toward the centroid of its proximal origin, thus reproducing the approximate line of action of the muscle-tendon region.

The moment arms and line of action for each sub-region of the subscapularis muscle were calculated across a series of static positions. The humerus was passively held at ***. . . insert test angles. . .*** of elevation in the scapular plane, as well as at ***. . . insert abduction external rotation positions. . .***.

Specimens were radiographed using X-ray fluoroscopy from ***. . . list the two directions. . .*** at each joint position (Fluoroscan InSight 2, Hologic Inc., Bedford, MA), and each muscle subregions line of action was calculated from its wire orientation with respect to the glenoid plane. A muscle subregions line of action was defined from the directional cosines of the vector formed between the most proximal tendon wrapping 'via point' (i.e. where the tendon loses contact with the hmerus) and the centroid of the tendon origin (**Ackland2019?**).

**TODO: muscle moment arm calculations. . .**

For each muscle subregion, average stability ratios were computed to assess the muscle's potential contributions to anterior/posterior and superior/inferior glenhumeral joint stability across the tested positions. Average anterior and superior stability ratios were calculated by dividing the average anterior/posterior and superior/inferior shear components of a muscle subregions line of action, respectively, by the average magnitude of its compressive component:

$$R_A = \frac{f_y}{|f_x|}; R_S = \frac{f_z}{|f_x|}$$

where $R_A$ and $R_S$ are the anterior and superior stability ratios, respectively; $f_x$, $f_y$ and $f_z$ are the directional cosines of the vectors used to calculate the line of action in the scapular reference frame (**ACkland2009?**). Where a muscle subregions stability ratio was greater than one it was considered as having destabilising potential, as the shear component of the line of action was larger than the compressive component (**Ackland2009?**). Conversely, awhere muscle subregions stability ratio was less than one it was considered as having stabilising potential, as the shear component of its line of action was smaller than the compressive component (**Ackland2009?**). A positive versus negative anterior stability ratio represented a muscle subregion with an anterior versus posterior shear component, respectively; while a positive versus negative superior stability ratio represented a muscle subregion with a superior versus inferior shear component, respectively (**Ackland2009?**).

Calculations were made for each specimen across the ***three*** subscapularis muscle split configurations.

We used a mixed effects linear model to examine changes in… line of action, moment arms… fixed effects of subscapularis muscle region, arm position and load, random effect of specimen…

## 3. Results

**TODO: add results**

```
## # A tibble: 96 x 7
##    region position load  plane variable     statistic     p
##    <fct>  <fct>    <fct> <fct> <chr>            <dbl> <dbl>
##  1 ss1    abd0     0N    SP    lineOfAction     0.924 0.463
##  2 ss1    abd0     20N   SP    lineOfAction     0.929 0.511
##  3 ss1    abd0     40N   SP    lineOfAction     0.932 0.534
##  4 ss1    abd90    0N    SP    lineOfAction     0.924 0.461
##  5 ss1    abd90    20N   SP    lineOfAction     0.913 0.376
##  6 ss1    abd90    40N   SP    lineOfAction     0.900 0.290
##  7 ss1    ABER     0N    SP    lineOfAction     0.960 0.813
##  8 ss1    ABER     20N   SP    lineOfAction     0.934 0.555
##  9 ss1    ABER     40N   SP    lineOfAction     0.931 0.526
## 10 ss1    APP      0N    SP    lineOfAction     0.923 0.451
## # ... with 86 more rows
```

### *3.1. Lines of Action*

#### *3.1.1. Scapular Plane*

Three-way repeated measures ANOVA found statistically significant subscapularis region x arm position () and subscapularis region x conjoined tendon load () interaction effects; and statistically significant subscapularis region() and arm position () main effects on muscle line of action in the scapular plane. The main effect of conjoined tendon load (), and interaction effects of arm position x conjoined tendon load () and subscapularis region x arm position x conjoined tendon load () on line of action in the scapular plane did not reach statistical significance.

Post-hoc analysis of subscapularis region x arm position effects found a statistically significant effect of arm position on the upper (), lower-middle () and lower () regions of the muscle. No statistically significant post-hoc effects (adjusted $p > 0.05$) were observed for conjoined tendon load on subscapularis region.

## 4. Discussion

**TODO: add discussion**

## 5. Conclusions

**TODO: add conclusions**

```python
#Basic print command
print('Using python in R!')

#Import pandas
```

```
## Using python in R!
```

```python
import pandas as pd

#Import seaborn and load dataset
import seaborn as sns
iris = sns.load_dataset('iris')
iris.head()
```

```
##    sepal_length  sepal_width  petal_length  petal_width species
## 0           5.1          3.5           1.4          0.2  setosa
## 1           4.9          3.0           1.4          0.2  setosa
## 2           4.7          3.2           1.3          0.2  setosa
## 3           4.6          3.1           1.5          0.2  setosa
## 4           5.0          3.6           1.4          0.2  setosa
```

## References