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Shoulder Implant Biomechanics

Material and Mechanics in Medicine HS 2019

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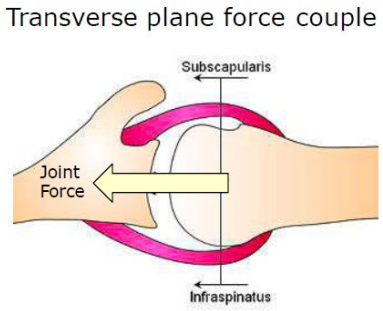
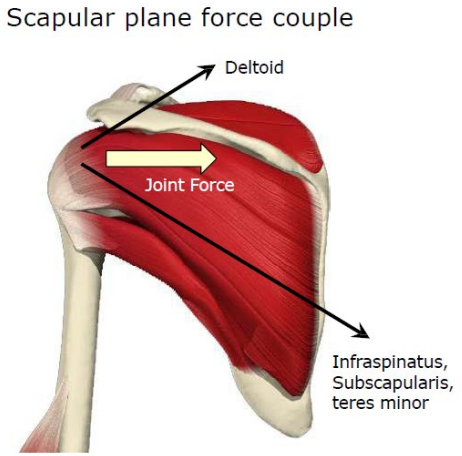
Shoulder Anatomy

- Stabilizers (Rotator Cuff):
  - Supraspinatus
  - Infraspinatus
  - Subscapularis
  - Teres Minor
- Prime Movers:
  - Delotoid
  - Pectoralis Major
  - Latissiumus Dorsi

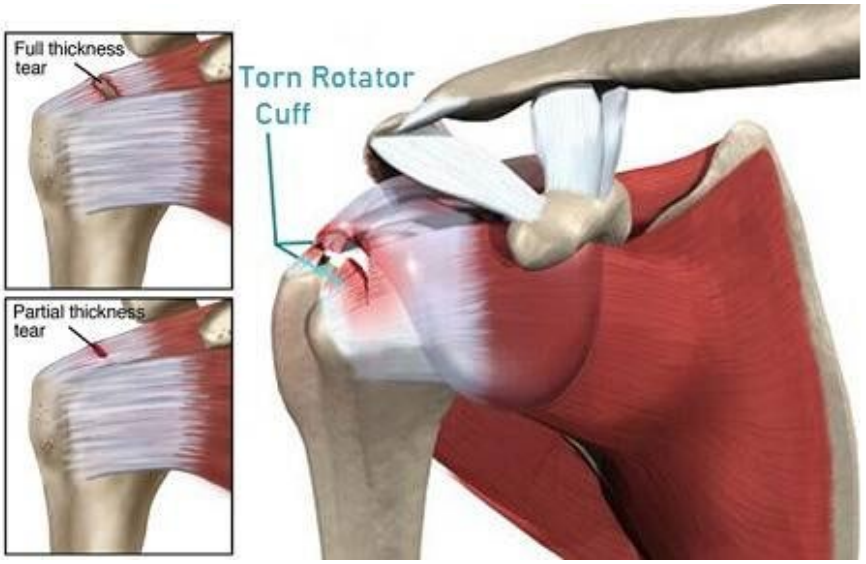




Shoulder Compications

50% of people in their seventh decade, and over 80% of people over the age of 80 will suffer a full-thickness rotator cuff tear

- Rotator cuff tears that are not repaired can lead to fatty infiltration
- Prolonged loss of upper limb motion due to joint pain and
- instability (rotator cuff tears) can lead to osteoarthritis.
- Osteoarthritis + rotator cuff tears = rotator cuff tear arthropathy



Shoulder Arthroplasty

- Anatomic total shoulder arthroplasty (ATSA)
  - Used to treat osteoarthritis, severe pain, reduced ROM, loss of muscle strength

  - Increased tendon contact pressures after surgery (tendon-metal contact)

- Reverse total shoulder arthroplasty (RTSA)
  - Used to treat rotator cuff tear arthropathy (GHJ unstable), trauma, resection, revision of ATSA

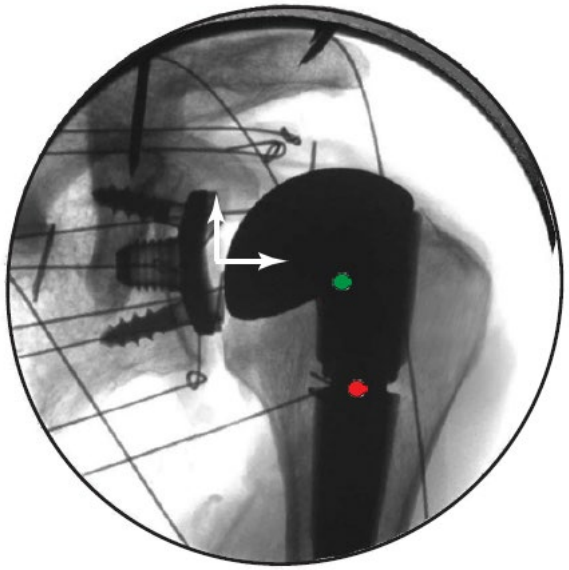
- Complications (mostly dislocations)

Muscles intact

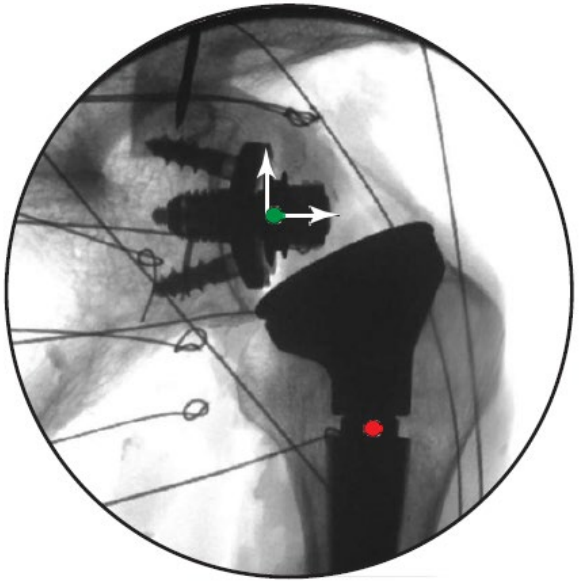
Muscles torn

Shoulder Arthroplasty

- Anatomical Total Shoulder Arthroplasty (ATSA)



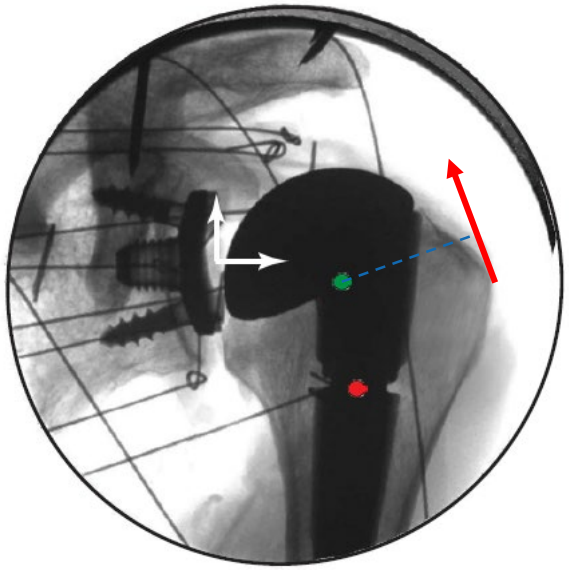
- Reverse Total Shoulder Arthroplasty (RTSA)



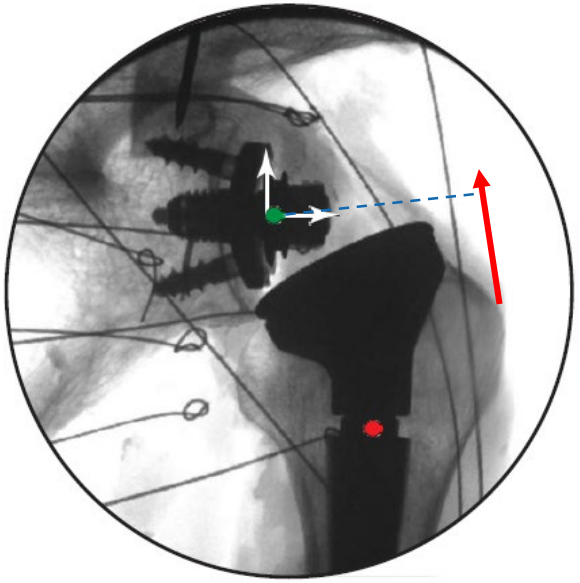
Relative to the anatomic shoulder, RTSA medialises GH joint center of rotation, and inferiorises the humerus

Shoulder Arthroplasty

- Anatomical Total Shoulder Arthroplasty (ATSA)
- Reverse Total Shoulder Arthroplasty (RTSA)



vs



Increase in muscle leverage after RTSA reduces muscle and joint loading (movements more efficient)

Relative to the anatomic shoulder, RTSA medialises GH joint center of rotation, and inferiorises the humerus

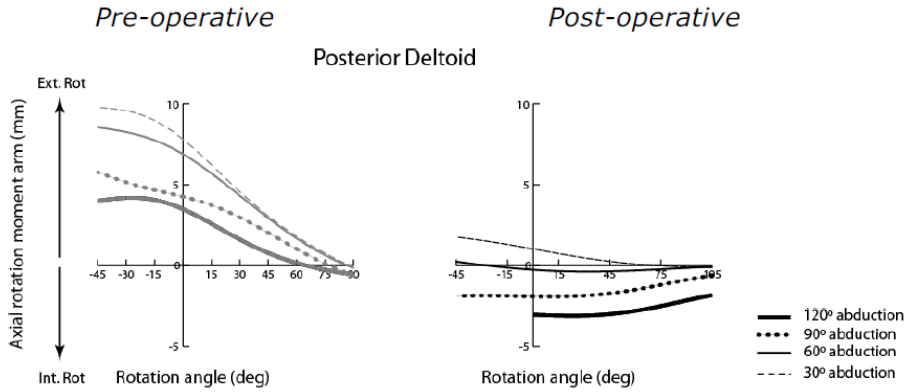
Reverse Total Shoulder Arthroplasty

Quantification of joint and muscle function after RTSA

- RTSA using measurement and modelling (i.e.,*in vitro, in vivo, in silico*):
- • Muscle moment arms
- • Muscle lines of action
- • Muscle force
- • Joint force
- • Bone and implant stresses

Reverse Total Shoulder Arthroplasty

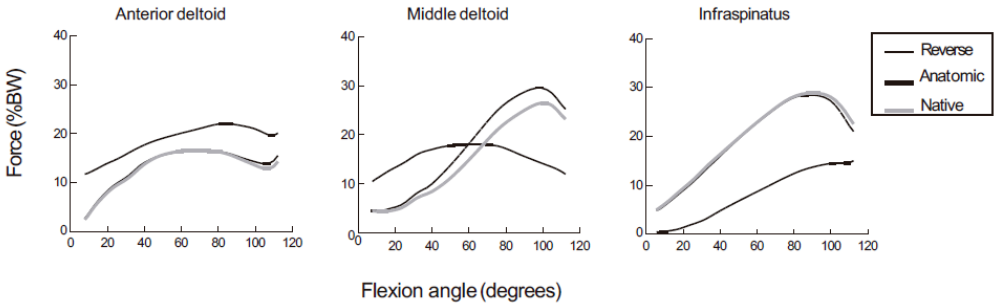
Muscle moments after RTSA



Post. deltoid also ADductor → ABductor

Muscle moment arms change significantly after surgery ($p<0.05$), e.g. Pre-operatively, the posterior deltoid was an external rotator during flexion, post-operatively it was an internal rotator (at high elevation)

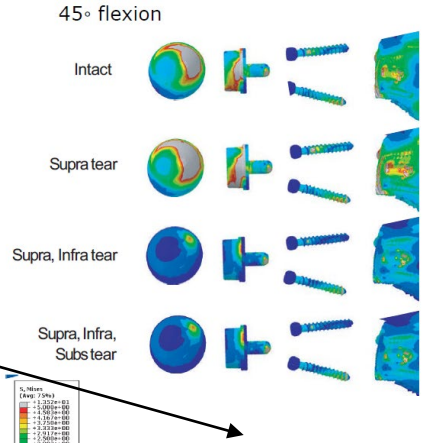
Muscle forces after RTSA



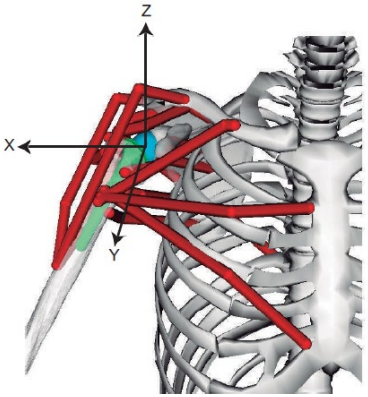
- Significantly smaller mean and peak deltoid and rotator cuff muscle forces post-operatively (due to larger lever arms)
- Muscle force peaks occur at different joint positions post-operatively

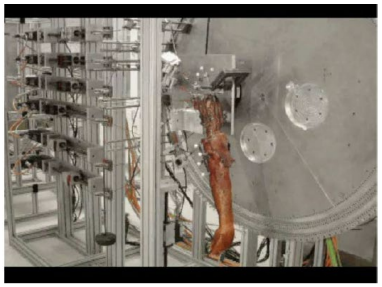
Muscle Force Models

RTSA using measurement and modelling (i.e.,*in vitro, in vivo, in silico*):

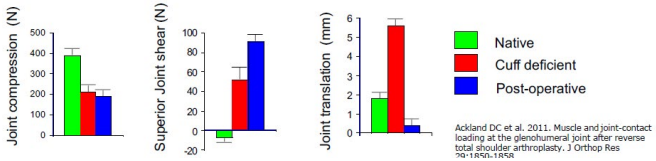


- Largest implant and bone stresses with intact and supraspinatus deficient shoulder
- Larger stresses in flexion than abduction
- Larger stresses in the superior screw than the inferior screw (baseplate bending forces)
- Tear to infraspinatus disrupts transverse-plane force couple (8x



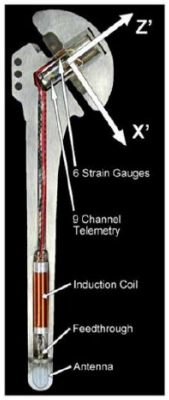


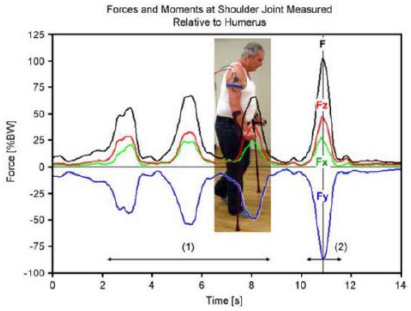
Mean glenohumeral joint translations significantly reduced post-operatively during abduction and flexion (p<0.001)



Ackland DC et al. 2011. Muscle and joint-contact loading at the glenohumeral joint after reverse total shoulder arthroplasty. J Orthop Res

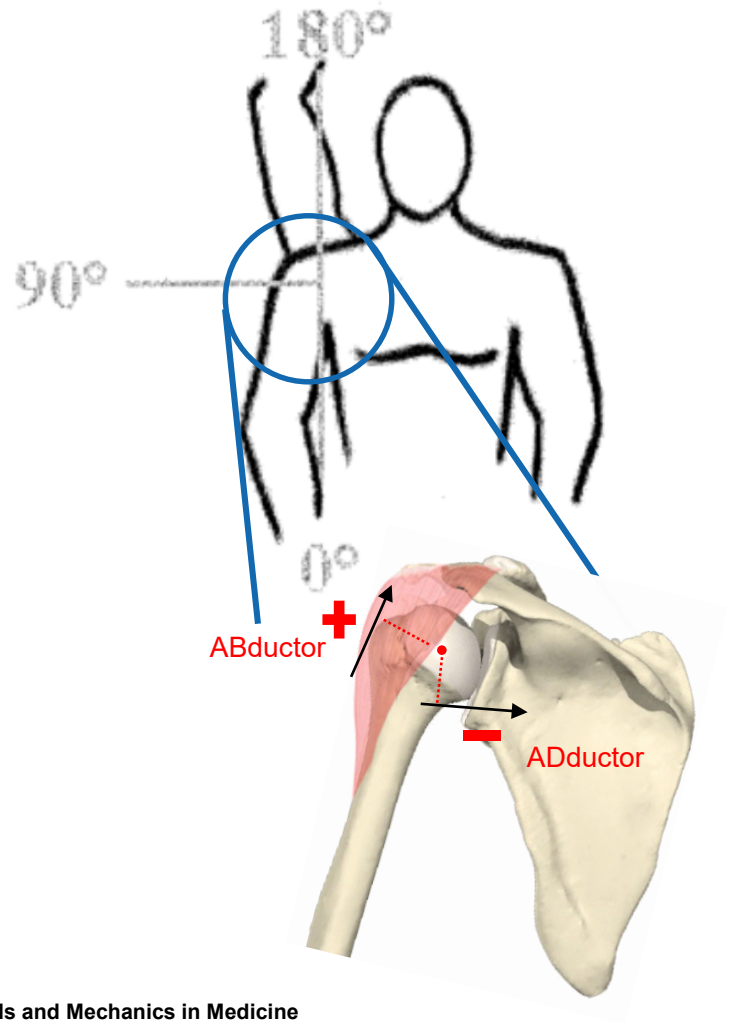
Instrumented implants

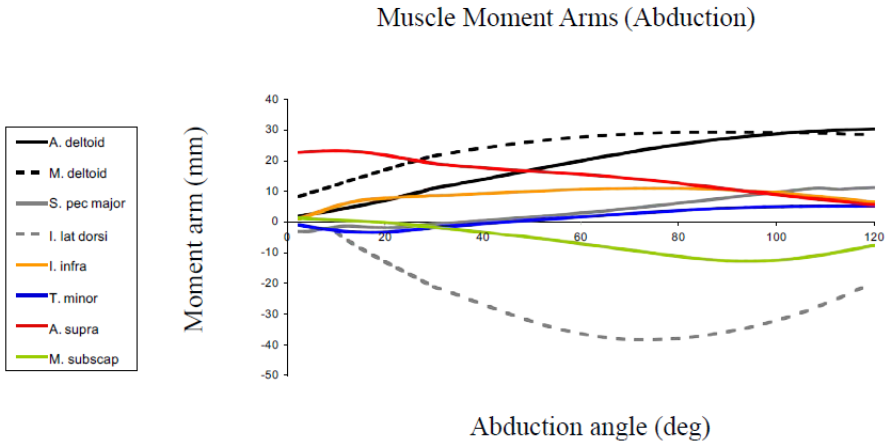




Strain gauging a human shoulder implant for measurement of joint contact force

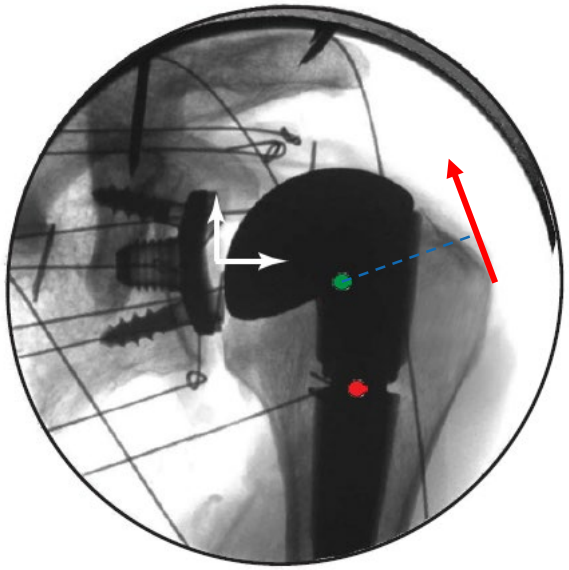
Exercise 1


180°
90°
0°
ABductor
ADductor

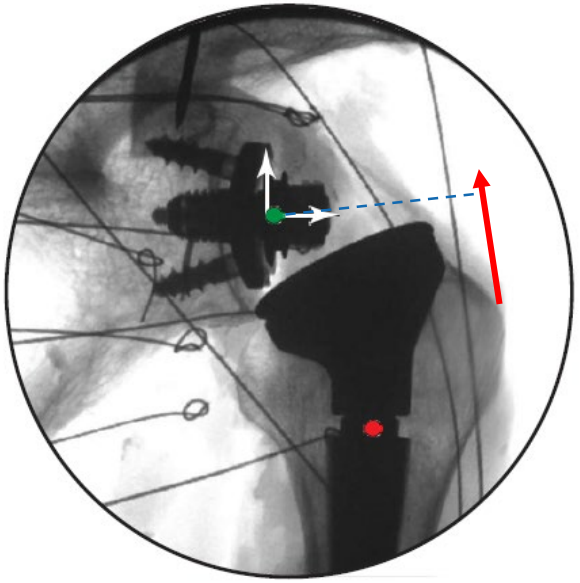

Muscle Moment Arms (Abduction)
A. deltoid
M. deltoid
S. pec major
I. lat dorsi
I. infra
T. minor
A. supra
M. subscap
Moment arm (mm)
40
30
20
10
0
-10
-20
-30
-40
-50
0
20
40
60
80
100
120
Abduction angle (deg)

Exercise 2

- Anatomical Total Shoulder Arthroplasty



- Reverse Total Shoulder Arthroplasty (RTSA)



2B: Static case → Force & Momentequilibrium

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Enjoy the holidays!