THE EXTERNAL AND INTERNAL GEOMETRIES OF RUGBY UNION PLAYERS' SHOULDER COMPLEX

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Introduction - When developing sports impact surrogates for injury mechanics research, assessments should be made of the anatomy and geometry the surrogate will be replicating. A surrogate removes the need for impact testing on humans or animals, providing a repeatable replication of a sports impact. This study aimed to assess the external and internal geometries of rugby players' shoulders to aid the development of a shoulder impact surrogate.

Methods - Nine male semi-professional rugby players of varying playing positions with a mean height of 1.87 ± 0.09 m and mass of 102.6 ± 9.75 kg were selected for the study and ethical approval obtained. The participant's shoulders were laser scanned using a handheld scanner (Artek Eva, Artec, Luxembourg). During the scans, participants were asked to bare their right shoulder and sit in an upright position. An external scan of the participant's shoulder region was then produced. These scans were then imported into computer aided design CAD) software Solidworks (Solidworks 2018, Dassault Systèmes, France) for analysis. Fig.1a shows an example of participant 1's rendered scan. Key geometries (Table 1) were then extracted for each participant using a measurement tool in the CAD software.

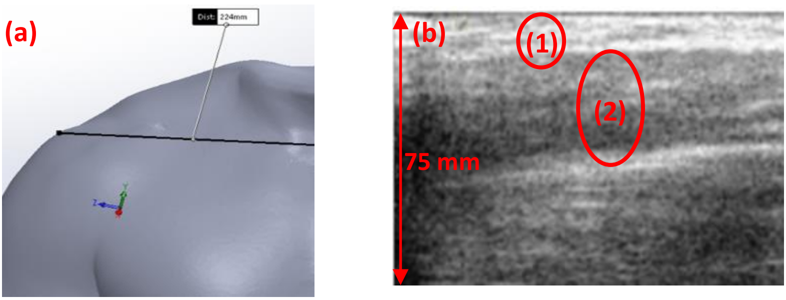

Fig. 1: (a) CAD image of shoulder scan with half shoulder width measurement annotated, (b) Ultrasound image of tissue layers taken superior to the central body of the Trapezius muscle layer, (1) - Skin, Adipose and Fascia Layer, (2) - Muscle Layer.

Ultrasound imaging of rugby players' trapezius, acromioclavicular (ac) joint and Deltoid regions were used to establish the layer thicknesses of the muscle,

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adipose and skin tissues. Six out of the nine participants from external body scanning were used. Scanning was completed using a Telemed ultrasound system (Echo Blaster 128, Milan, Italy). Participants were asked to bare their right shoulder and sit in an upright position. Three anatomical landmarks on their shoulder were identified; the midpoint between the acromion and the seventh cervical vertebra on the trapezius; the ac joint; and the most distal part of the deltoid. Ultrasound gel was applied to the transducer and placed with as little pressure as possible to not distort the internal geometries of each landmark; ultrasound images could then be captured. Images were then exported to processing software and measurements of tissue depths were made (Table 1).

Table 1: Shoulder measurements from external and internal scanning (mean values ± SD).

External measurements	**Deltoid width**	**Half shoulder width**	**ac joint to trapezium insertion**	**Central spine of scapula to central clavicle**
Length (mm)	168 ± 11	22 5± 10	175 ± 20	155 ± 12
Internal measurements	**Trapezius**		**Deltoid**	
	Muscle	Skin and Adipose	Muscle	Skin and Adipose
Thickness (mm)	17 ± 2.0	5.6 ± 2.0	33.2 ± 2.7	6.0 ± 1.7

Results and Discussion - The measurements presented in Table 1 provide key information for the development of a human shoulder surrogate. As well as this, the data can be used to compare against the general population. Average trapezius and deltoid muscle tissue thicknesses have been found to be 11.9 mm [2] and 29.0 mm [3]. This is 5.1 mm and 4.2 mm less than what was found in the current study. When considering development of a shoulder surrogate, the 3D scans of the participant's external shoulder geometries were used to develop a design of the shoulder surrogate. This was then used to develop a mould where manufacturing techniques like 3D printing were utilised. The assessments carried out in the current study also show the shoulder to be a complex joint. It includes many other tissues including ligaments, tendons and cartilage. However, when designing human body surrogates, simplifications to its anatomy and geometries may need to be made for ease and repeatability of fabrication.

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2. Meyer, D. C., et al, (2013). Deltoid muscle shape analysis with magnetic resonance imaging in patients with chronic rotator cuff tears. BMC Musculoskelet. Disord 14:1-7.

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