

Comparison of Rotator Cuff Muscle Architecture between Humans and Selected Vertebrate Species

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INTRODUCTION

One of the most common causes of pain and disability in the upper extremity is injury or disease in the shoulder, specifically in the rotator cuff muscle group. Although a variety of animal models have been used to study rotator cuff disease, there have been no formal reports comparing the organization of the musculature in these different species. Therefore, the goal of this study was to characterize and compare architectural data between the human rotator cuff muscles and those of several species commonly used in rotator cuff research.

METHODS

Eight animals commonly used in rotator cuff research were selected for the study: mouse (*Mus Musculus*), Sprague-Dawley rat (*Rattus norvegicus*), New Zealand White rabbit (*Oryctolagus cuniculus*), dog (*Canis familiaris*), Yucatan mini-pig (*Sus Scrofa*), sheep (*Ovis aries*), goat (*Capra hircus*), and cow (*Bos taurus*). Shoulders were harvested and fixed in 10% buffered formaldehyde. After fixation, the shoulders were stored in phosphate buffered saline (PBS). The outer layers of skin, fat, and overlying muscles were dissected away until the muscles of interest were exposed. The rotator cuff muscles were then excised for further analysis.

Muscle architectural measurements were made on the four rotator cuff muscles according to methods previously described (Lieber *et al.* 1990). The specific muscles studied were Supraspinatus (Sup), Infraspinatus (I), Teres minor (TM), and Subscapularis (Sub). Briefly, muscle mass (m), muscle length (L_m), and fiber length (L_f) were measured for each muscle. Fiber bundles from two

to four predetermined regions were microdissected and sarcomere length (L_s) for each fiber bundle was measured using laser diffraction using the first to first order diffraction pattern (Lieber *et al.*, 1994) to calculate normalized fiber length (L_{fn}) and physiological cross-sectional area (PCSA) as previously illustrated (Lieber *et al.* 1994).

Scaling of muscle architecture with body mass across species was examined using linear regression of log transformed variables. Animal mass was treated as the independent variable and the architectural variable (PCSA or L_{fn}) was the dependent variable. The coefficient and the exponent of the exponential equation, $y=aM^b$ (where y is the architectural variable, a is the coefficient, M is the animal mass, and b is the scaling exponent) were used to compare scaling relationships among the rotator cuff muscle.

RESULTS AND DISCUSSION

PCSA varied in all muscles within and between each species. However there were similarities in an individual muscle's contribution to total rotator cuff PCSA between species. In the dog, rat, mouse and rabbit models, the subscapularis had the largest PCSA, contributing 45%, 47%, 48%, and 41% respectively to total rotator cuff PCSA, which is comparable to the human subscapularis which contributes 42%. The other muscles of the rotator cuff for these species also shared similar percentages to the human rotator cuff muscles. The goat, sheep, pig and cow were similar to each other with the infraspinatus having the largest PCSA (39%, 40%, 39%, 50%, relatively, of total rotator cuff PCSA) but less similar to human relative to the species mentioned above (Figure 1).

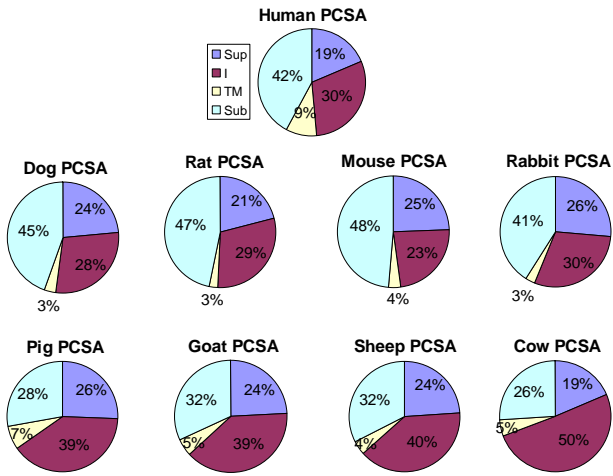


Figure 1. Percent contribution of each muscle to total rotator cuff PCSA: Supraspinatus (Sup), Infraspinatus (I), Teres Minor (TM), Subscapularis (Sub).

Log transformed data revealed normalized fiber length and PCSA all scale linearly with body mass ($0.86 \leq R^2 \leq 0.99$) (Figure 2, Table 1). Analysis of the scaling exponents suggests geometric scaling rules between species.

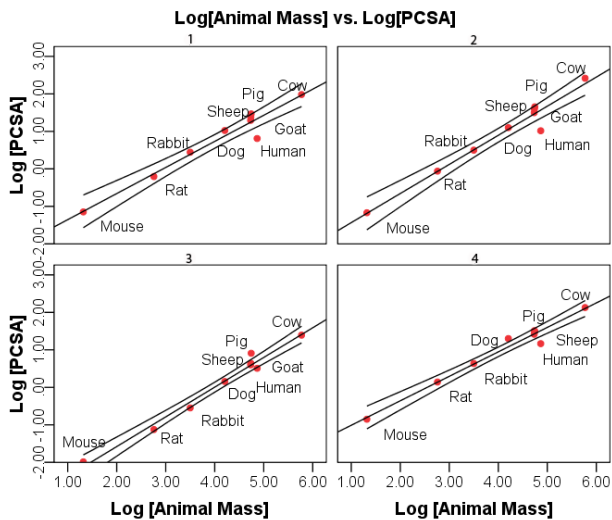


Figure 2. Relationship of muscle PCSA to body mass. Each rotator cuff muscle PCSA scales linearly to body mass. (1-Supraspinatus, 2-Infraspinatus, 3-Teres Minor, 4-Subscapularis)

CONCLUSIONS

Although none of these animals is an ideal match to the muscular anatomy of the human shoulder, our data shows that the relative PCSA of the rotator cuff muscles of the smaller animals, dog, rabbit, rat and mouse more closely match those of the human. Architectural properties such as fiber length and PCSA scaled geometrically with animal mass across all species. The use of animals in research has helped further the understanding of human disease. These data will be useful in selecting the appropriate animal model for future studies involving the rotator cuff.

REFERENCES

- Lieber *et al.* (1990). *J. Hand Surg.* **15A**, 244-250.
- Lieber *et al.* (1994). *J. Neurophysiol.* **71**, 874-881.

Table 1. Regression exponents and coefficients for L_{fn} and PCSA relative to body mass.

Muscle	L_{fn}			PCSA		
	b	a	R^2	b	a	R^2
Supraspinatus	0.339±0.017	0.168±0.073	0.983	0.696±0.061	-2.050±0.259	0.949
Infraspinatus	0.295±0.032	0.182±0.136	0.925	0.776±0.061	-2.209±0.260	0.958
Teres Minor	0.303±0.047	-0.039±0.200	0.856	0.792±0.044	-3.163±0.189	0.978
Subscapularis	0.325±0.043	-0.081±0.184	0.890	0.652±0.042	-1.662±0.180	0.971