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

INTRODUCTION:
One of the most common causes of pain and disability in the upper extremity is injury or disease of the shoulder, specifically the rotator cuff muscles. 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 across different species. Therefore, the purpose of this study was to characterize and compare architectural data of rotator cuff muscles across species used in rotator cuff research.

METHODS:
Ten animals commonly used in rotator cuff research were selected: 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), cow (Bos taurus), chimpanzee (Pan troglodytes), and capuchin monkey (Cebus capucinus). Shoulders were harvested and fixed in 10% buffered formaldehyde. After fixation, shoulders were stored in phosphate buffered saline (PBS). The outer layers of skin, fat, and overlying muscles were dissected away exposing the muscles of interest and rotator cuff muscles were excised for further analysis.

Muscle architectural measurements were performed on the four rotator cuff muscles as 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 across species of muscle architecture with body mass was examined using linear regression of log-transformed data. Animal mass was treated as the independent variable and the architectural variable (PCSA or L_{fn}) as the dependent variable. The coefficient and 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 rotator cuff muscle.

RESULTS:

PCSA varied in all muscles within and between species. There were, however, similarities in an individual muscle’s contribution to total rotator cuff PCSA among some species. The chimpanzee had the greatest overall similarity to humans with all PCSA percentages being within 4% of the corresponding human values. 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. However, goat, sheep, pig and cow were similar to each other with the infraspinatus having the largest PCSA (39%, 40%, 39%, 30%, relatively, of total rotator cuff PCSA) but were much less similar to humans compared to the species mentioned above (Figure 1).

Log transformed data revealed that normalized fiber length and PCSA both scale linearly with body mass (0.86 ≤ R^2 ≥ 0.99) (Figure 2, Table 1). Analysis of the scaling exponents suggest simple geometric scaling rules among species.

### DISCUSSION:
Of the species examined, the chimpanzee is most closely related to the human, so it is not surprising that these species share similar shoulder musculature anatomy. Of the non-primates, our data show that the relative PCSA of the rotator cuff muscles of the smaller quadrupeds—dog, rabbit, rat, and mouse—most closely match those of the human. Architectural properties such as fiber length and PCSA scale 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 an appropriate animal model for future studies involving the rotator cuff.

### SIGNIFICANCE:
To determine the best model for a specific human disorder, it is necessary to fully understand the characteristics of each model. The thorough characterization we have performed will allow physicians and scientists to make informed research decisions about rotator cuff repair and choice of experimental models.

### REFERENCES:
Lieber et al. (1990). J. Hand Surg. 15A, 244- 250