TRANSVERSE QUASI-STATIC COMPRESSION ON MUSCLE AT HIGH STRAIN: MECHANICAL PROPERTIES IDENTIFIED FROM A GEOMETRICALLY PRE-PERSONALIZED FINITE ELEMENT MODEL

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INTRODUCTION
Numerical models of the human body request information on body parts and especially on muscles. Many experiments have been done to evaluate muscle's mechanical properties in its longitudinal direction [1,2,4]. Whereas, transverse properties are not well known [3].

The aim of this study was to evaluate muscle's behavior in its transverse direction with a quasi-static compression test. The results were exploited with a pre-personalized finite element model to identify muscle's characteristics.

METHODS
Six long chest expanders of the fingers muscles were harvested from three young pit-bulls with their aponeurosis and tendons. They were frozen at -20°C. Samples were slowly thawed 12 hours before testing at 4°C in a physiological solution.

Each specimen was weighed and scanned with Handyscan3D© (Creaform, Canada) to obtain its geometry. Then muscle was placed on the lower plate of a hydraulic compression testing machine (INSTRON 8500) that compressed the muscle until a load of 2N. 10% crushing was imposed at the speed of $1 mm.min^{-1}$. The percentage of crushing is the ratio of machine displacement with the highest initial thickness of the muscle. Cyclic compressions were applied with amplitude of 3% crushing. Finally, muscle was compressed at $1 mm.min^{-1}$ speed until 50% crushing.

A finite element simulation of each compression test was performed. Muscle geometry was respected. There were 288 elements and 425 nodes in each model. The material law was elastic and characterized with Poisson's ratio fixed to 0.495 and Young's Modulus. Simulation conditions were the same as for the experiment. Young's Modulus was identified using inverse method.

RESULTS AND DISCUSSION
Figure one presents the curves "load/percentage of crushing" for the six tested muscles (Figure 1). Their exponential appearance is in accordance with the literature; Sten-Knudsen [4] mentioned this behavior for the longitudinal direction.

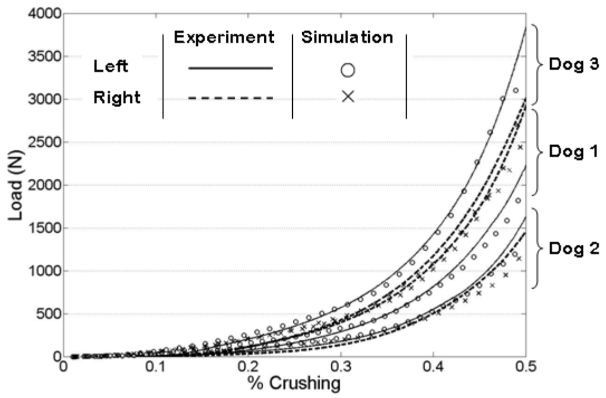

Figure 1: Compression experiments and simulations

Young's modulus identified with simulations (Table 1) has a mean value of 1.85MPa. Aimedieu et al. [3] found a Young's Modulus comprised between 0.15 and 6MPa for porcine muscles.
The use of a linear elastic law proves that muscle's non linear behavior is not only due to its material properties but also to its geometry.

CONCLUSIONS
These series of experiments and simulations with a simplified finite element model of muscle give further information on muscle's mechanical properties. This model will next be integrated in more complex modeling adapted to human being. As the material law is a linear elastic law, simulations will compute easier.

REFERENCES
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Table 1: Young's Modulus of the 6 tested muscles using inverse method combining experiments and finite element model.

Specimen	**M-1-left**	**M-1-right**	**M-2-left**	**M-2-right**	**M-3-left**	**M-3-right**
Young's Modulus (MPa)	1.47	2.19	1.04	0.76	3.35	2.27