## A STRAIN-GAUGE UNIAXIAL LOAD CELL TO EVALUATE MUSCULAR STRENGTH LEVEL IN ISOMETRIC EXERCISE.

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### INTRODUCTION

"Muscle strength is defined as the magnitude of the torque exerted by a muscle (or muscles) in a single maximal isometric contraction of unrestricted duration" (Atha, 1981). Strength that depends on neural, mechanical and muscular factors is defined by the torque rather the force exerted by a simple joint system for purely pragmatic reasons because the direct measurement of the muscular force would involve either the attachment of a force transducer to the muscle tendon or a means of converting the myoelectric activity (EMG) into a measure of muscular force. Given that, thse are not simple procedures it is much easier to measure the torque in human subjects. "Strength diagnosis" (Schmidtbleicher, 1992) by means of strength and power tests has been considered very useful to identify talents or to control the evolution in the training or rehabilitation progress. Besides, the results of a specific test batteries make possible the indirect estimation of the global level of muscular strength by means of such parameters like the "Indice Globale Dinamometrico" (Dal Monte, 1983) that is an index expressing the level of the strength of different muscular groups in isometric conditions. Finally, the maximum muscular isometric strength and the rate of strength development are considered as very important qualities respect to the athletic performance (Wilson and Murphy, 1995). The purpose of this study is the design and development of a strain-gauge uniaxial load cell measurement chain enabling the measurement, store and representation of the well established mechanical parameters to evaluate muscular strength in isometric conditions.

### METHODS

The followed methodology consists in the next steps (Figure 1):

- select the material on the basis of its mechanical properties elastic limit and modulus of elasticity or Young´s modulus (E = stress/strain)
- select a logical diameter for the steel ring (2R) and width (a)
- calculate the strain ($\varepsilon$) that expresses the amount by which the steel ring will deform for a supposed maximum stress ($\sigma$) lower than the elastic limit ($\varepsilon = \frac{\sigma}{E}$)
- with ($\varepsilon$) and the maximum force calculate the thickness of the steel ring (e)

$$e = \sqrt{\frac{3FR}{Ea\varepsilon}(1-\frac{2}{\pi})}$$

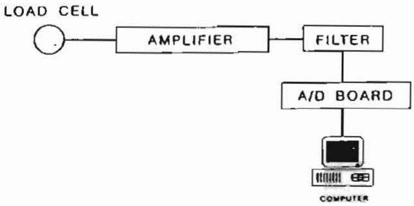
- the development of the electronics of the measurement chain that includes:
  - the load cell with a Wheatstone circuit
  - the amplifier

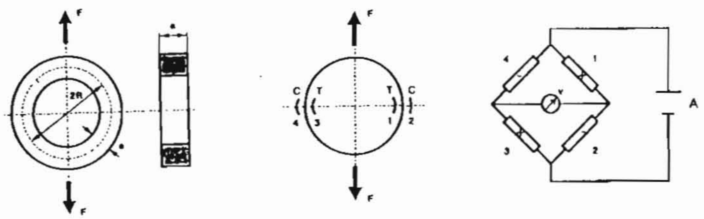
a low-pass analog filter

the A/D converter

the personal computer and the software application

- the calibration of the load cell took place using an INSTRON electrohydraulic testing system ($r = -.999$, $p < .00000$)
- the development of the software that permits the acquisition and representation of the measurement data in real-time providing the possibility for feedback applications.




$$\varepsilon = \frac{3FR}{Eae^2}(1-\frac{2}{\pi})$$

**Deformation in a steel ring**

**Location of strain gauges**

**T: traction**

**C: compression**

$$V=\frac{A}{4}(4G\varepsilon$$

**G: gauge factor**

**V: measured voltage**

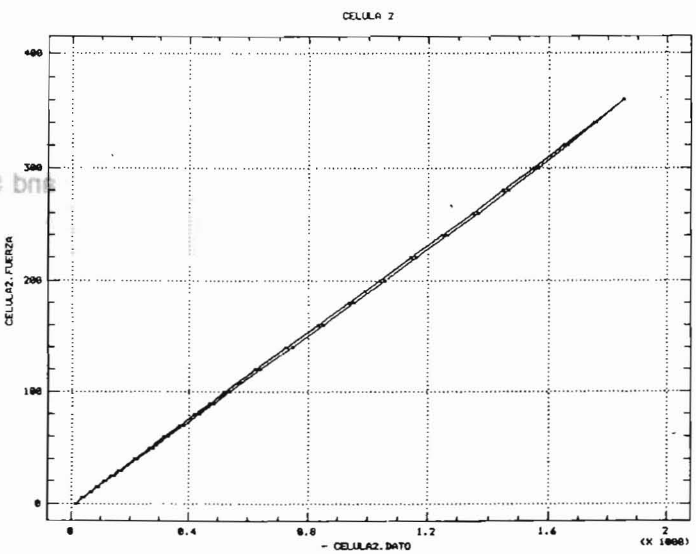



Figure 1. Detailed representation of the components of the uniaxial load cell system with its calibration curve.

## RESULTS

The performance characteristics of the here presented strain-gauge uniaxial load cell measurement chain are:

measurement range : up to 3500 N
precision : ±5 N
sampling rate : 500 Hz

The mechanical parameters that can be obtained to evaluate the level of muscular strength in isometric conditions are:

- the percentage of the peak value of the force exerted on the uniaxial load cell for in a maximum voluntary isometric muscular contraction respect to the time
- the gradient of the force vs. time curve, that expresses the rate of force development up to any point of the force time curve curse, dividing the force obtained by the time taken to attain that point
- a fatigue index estimated by means of the time that a subject can maintain a certain level of absolute or relative force in isometric conditions or the maximal force that a subject could maintain for a specified time period.

Finally, for the correct use of the system, it is very important to take care of standarizing the relative position of the body segments (posture). The variability in positioning would cause a marked variation in the obtained results. Even when the test is for a single joint only, it is necessary to standarize other joint angles. For example, the isometric strength force measured of the knee extensors seems affected by variation in the hip joint angle because of the rectus femoris length variation.

## CONCLUSION

Convenient technical characteristics recommend the use of this uniaxial load cell system to evaluate the strength capacity of different muscular groups in isometric conditions once the relative position of the body segments (joint angles) is standarized, even if the test is for a single joint only.

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