Introduction
Piezoelectric ceramic plates have been widely used for pressure measurements, mainly due to their rapid response to dynamic pressure signals and powerless sensing characteristics.
In this work we present the ability of such ceramics in measuring shear forces induced by a piezo impact device (piezo-pecker system [1]) placed on the top of our sensing piezoelectric ceramic. The induced impact force can be controlled in time and amplitude. Measuring shear forces can be interesting in many biomedical applications, such as prostheses interfaces to evaluate or predict their displacement [2], or even, as one of the methods of preventing ulcers in the diabetic foot, complementing information on feet plantar pressures [3].

Materials and Methods
The so-called piezo-pecker system consists on a multilayer thickness-mode piezo glued in between two masses \( m_1 \) and \( m_2 \), \( m_1 > m_2 \). The symmetry axes of these three elements lie on the same horizontal plane. Mass \( m_2 \) is positioned on the top surface of our sensing piezoelectric ceramic plate (Philips 10x10x1mm3 pzt). In this way, mass \( m_2 \) is allowed to move freely, while mass \( m_1 \) is subjected to a friction force in the contact surface, which in the limit would tend to infinity when this mass is glued to the sensing piezo. Shear forces are produced when the piezo-pecker system is excited with fast rising (hundreds of \( \mu s \)) and slow falling (tens of ms) voltage pulse, resulting in a applied signal frequency of about 50 Hz. As a result, the piezo-actuator expands rapidly, generating an horizontal impact force with the same duration of the voltage rising edge, contracting afterwards, very slowly. The amplitude and the rising and falling edges of the applied voltage pulses were varied using a Labview™ application to control the home-made piezo-amplifier [4]. The shortest rising time that can be achieved with this amplifier is about 200 \( \mu s \). After insulating the connecting cables to avoid induced currents and making sure the electrical connections all had the same voltage reference, we applied different voltage amplitudes and also for the same amplitude vary the voltage rising time.

Results and Discussion
As expected, we observed a linear dependence of the output sensing voltage with either the amplitude of the applied signal and the duration of its rising edge (Figure 1 and Figure 2).

Due to the dynamic response of the piezo, the obtained result shows that faster signals result in higher output voltages. As the force exerted upon a piezoelectric ceramic is related to the charge generated on the ceramic electrodes, also the output amplitude variation is clearly due to shear force variation and no other effect. An average slope of about 2.7 mV/V was obtained representing the amplitude transfer rate from the piezo-pecker to the sensing piezo.

Conclusions
The results indicate that thickness-mode piezoelectric ceramics can be used to measure shear forces. With adequate layout and choice of materials, these piezoelectric properties can be used in biomechanical applications.

References