ELECTRONIC SYSTEM TO MEASURE PLANTAR FORCE DISTRIBUTION IN PATIENTS

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This article describes an electronic system, projected to measure the force distribution under patients' foot soles by instrumented soles with sensors. The system is basically composed of load cells installed in the soles, signal conditioning circuit, interfacing circuit and a computer, from which the measurement results can be read. It is possible to measure static and dynamic forces. Data visualization on the computer screen is displayed by a Visual Basic program. The system presents linear response with the applied force, small hysteresis, precision higher than 99.4%, in addition to its simple operation and handling. It could be used by sports and fitness professionals and other health area professionals to assist in the evaluation of specific programs that aim at increasing athletes' performance.

KEYWORDS: instrumented soles, load cell, sensors.

INTRODUCTION:

Identifying factors that involve psychomotor aspects are of utmost importance for physical performance improvement, for lesion prevention, progression of post injury treatments and for gait verification in athletes. For this, biomechanics makes use of resources such as safety equipment, devices for specific tests, and kinematics gait analysis. Biomechanics studies the external and internal forces (Amadio, 2000). Gravity, inertia and ground contact are examples of external forces. The internal forces are composed of muscular and articulate forces that relate to movement and mechanical loads of the lower members. It is vital to analyze these forces in order to improve movement techniques or adjust the manner of stepping during displacement, and the cycle of the gait, as well as equilibrium and unloading weight of the lower members. Menegaldo (2003) developed mathematical models of the dynamics and equilibrium position in human beings. The method, proposed by Menegaldo, uses a mathematical muscle model elaborated by Zajac (1989) and versions of the model by A. V. Hill (1938), particularly, concepts as neural activation, force-speed and force-length for analysis of the neural-muscle and muscle-skeletal physiology.

This work describes the implementation of instrumented soles with sensors, as a tool for biomechanical analysis, quantitative verification of an athlete's gait and weight distribution in different parts of the foot, besides the movement and displacement through the articular system. Another important application of this system is verification of the support, balance and double support phases in an athlete's gait and step, in some sportive modalities, with emphasis for modalities where the body interacts more with the ground. It can be used by sports trainers and occupational therapist to verify and increase the performance of normal athletes during sports practice, or used for lesion prevention or to assist during the rehabilitation phase in injured athletes. This electronic system, used jointly with the Menelgado and Zajac models, makes possible dynamic analysis of the muscle-skeletal movements.

This way, after measurements are performed with the system, special shoes or even special insoles for each type of gait can be indicated, with the purpose of correctly positioning the

articular joints to improve static and dynamic equilibrium, and the correct placing of the foot on the ground. This might provide assistance to enhance athletes' performance.
Sensors were implemented and placed in adequate places of the plantar arch. The plantar arch has three arches and three support parts (A), (B) and (C), as seen in Figure 1. These support spots are in the contact zone with the horizontal level or plantar impression (KAPANDJI, 1990). It proportionately associates all of the articular osseous elements, the ligaments and muscles of the foot, in such a manner that the curvature and elasticity generate adaptation to the irregularities of the ground for the transmission of force and body weight, considering the best mechanical condition for the ground (KAPANDJI, 1990).
The purpose of the implemented electronic system is to monitor in a computer screen, the weight discharge distribution into areas of the plantar arch and hallux, facilitating a more rigorous indication of special footwear for athletes.

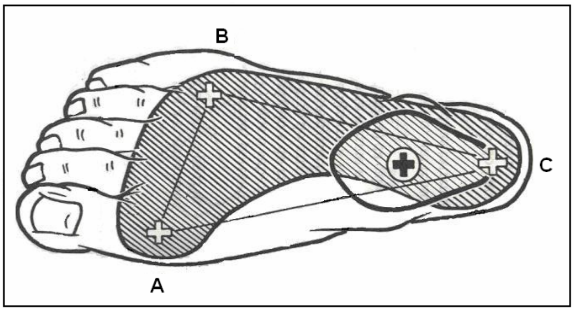

Figure 1: Plantar arch.

METHOD:

The sensors used were metallic strain gauges type diaphragm (Excel, PA-09-228CA-350L), connected to a full Wheatstone bridge, installed in load cells made of stainless steel. The signal, in the signal conditioning circuit output, is connected to an interfacing circuit, whose most important components are microcontrollers PIC18F4550 and ATMEGA8. The load cells were calibrated through known weights and data visualization on the computer screen is by a program elaborated in Visual Basic language.

RESULTS:

Figure 2 shows the response curve of one of the load cells installed in the insoles, which can measure forces up to 300 N. It is observed that the response is linear, with small hysteresis.

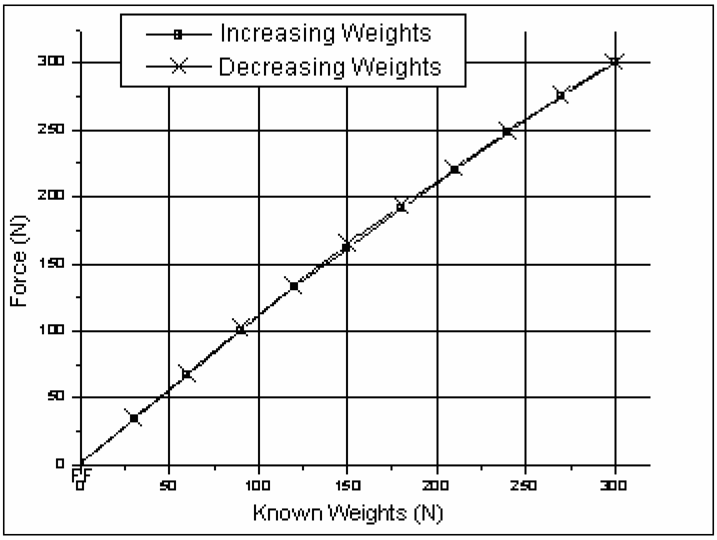

Figure 2 – Response of one of the insole load cells.

All of the implemented transducers presented linear response, with small hysteresis, precision higher than 99.4%, resolution better than 0,5 N, and adjusted dynamic band for monitoring of forces exerted in the heel regions, metatarsus 1, metatarsus 5 and hallux, of athletes with corporal mass of up to 100 kg. Figure 3 illustrates the results obtained when forces exerted in the regions of metatarsus 1, metatarsus 5, heel, and hallux of a athlete, with 60 Kg corporal mass, were monitored.

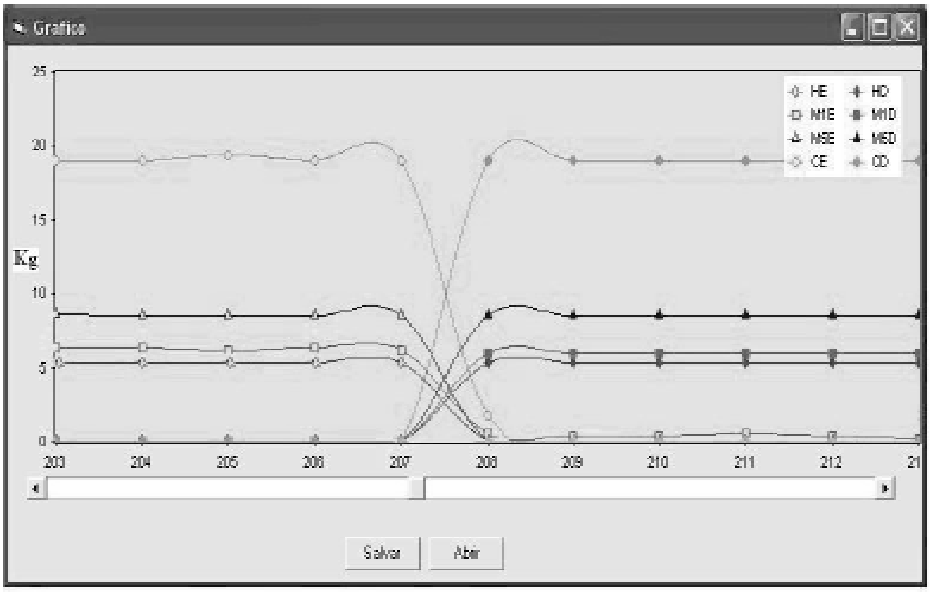

Figure 3: Dynamic test performed with the implemented system.

DISCUSSION:

Through load cells installed in insoles and by a program developed in Visual Basic language, professionals of the health area and physiotherapy have the possibility to monitor athletes during gait, in resting state or to simulate situations that occur during a determinate exercise and to concisely and quantitatively verify the effort transmitted to the ground by the lower members. A program developed in Visual Basic enables the therapist and/or trainer to elaborate an electronic handbook of the individual. In this handbook, all of the information related to the athlete could be stored, from personal data to the results of measurements and tests. The visualization of the tests could be done by means of line or bar charts.

CONCLUSION:

The implemented electronic system presents linear response, good precision and resolution. The system is versatile and can store, in memory, the results of the diverse measurements carried out throughout the specific length of time, facilitating progress follow-up of a definitive physical treatment to which the athlete is being submitted. Compared to the systems presented in literature, this system is versatile and modern, and does not need special data acquisition cards.

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