PORTABLE INSTRUMENT TO ANALYZE DIFFERENT PARAMETERS DURING LONG PERIOD EXERCISES

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INTRODUCTION: In some sport activities the foot is one of the parts of the human body submitted to particular stress. The study of pressures inside footwear, during the different phases of activity, is one of the most interesting aspects to be considered. The information that could be obtained are related to only one physical entity, which represents the force transferred to the ground. Studying particular athletic actions could be insufficient. For this reason a project was started to integrate more sensors in order to obtain information from different entities. Another goal of the project was to produce a device which is light, portable, of small dimensions, and easy for the athlete to use. All the measurements we want to obtain refer to entities already known and normally measured using typical laboratory equipment or in an invasive method, our purpose was to make the same measurement in an non-invasive way.
The primary goal of this study was to verify the real possibility to use this tool and to check the possible limitations.

METHODS: The first goal was the definition of entities to measure in order to define the characteristics of the global system. Besides the pressure we have considered the following variables which could be useful for a clinical and research point of view: the acceleration in two directions to obtain the movement of different body segments, the ECG signal, the control for some muscle activity, the amount of oxygen in the blood. To reach these goals a special central unit has been developed. The heart of the system is a 16 bit HITACHI RISC micro processor working at 20 Mhz. In the main board we mounted the following units: clock, 1 Mbytes of RAM memory, interfaces for a graphic display, keyboard and memory card with 16 Mbytes. Two serial interfaces are also present. The system can interface different analogue signals using 8 internal 10 bit A/D converters or can obtain converted values through the data bus, allowing the use of an external A/D converter for faster or more precise (12 bit) converters. The interface to the different sensors has been developed in a modular board so that the system can be structured depending on need. Below is a description of the different sensors.

PRESSURE SENSORS: Insoles with 64 resisive-type sensors (FSR) were used. Each insole foresees a particular kind of interface that utilizes an A/D channel per each insole. The acquisition standard frequency in the typical configuration reaches 100 Hz in the fixed scanning mode, or about 150 Hz in the variable scanning mode. The frequency in the fixed scanning mode is necessary to synchronize other sensors or external devices.

ACCELERATION SENSORS: These are capacitive-effect sensors made by an ANALOG DEVICE (ADG05). An accelerometer that can measure up to +/-5 g of acceleration and has the possibility of setting the reference value was chosen. This kind of accelerometer contains the necessary conditioning-electronic and it is possible to use it both in continuous and in alternate configuration. Sensors of acceleration have been integrated in small electronic-circuits to give the possibility to apply them to different segments of the body, each circuit can carry two 90° positioned accelerometers making possible the evaluation of the bi-dimensional space.

ECG SENSORS: The system can integrate an 8 channel electrocardiograph in order to reconstruct the 12 standard derivation signal. The input amplifiers have been designed following the electrocardiography standard with a Common Rejection Ratio greater than 100dB and a band from 0,005 Hz to 250Hz. With the 12 bits converter and a sampling frequency of 500Hz, the system follows the specific of the C.S.P. for the computerized ECG analysis. The standard RED DOT electrodes have been used, connected in a conventional way.

OPTO SENSORS for oxymeter: The percentage of oxygen saturation is the ratio between the oxygenated hemoglobin concentration and the sum of the oxygenated and not oxygenated hemoglobin concentration. The basis of the oxymetry is a knowledge of the hemoglobin absorption curves and the Beer-Lambert law of the light absorption of different materials. The measurement was made using the blood pulsating effect in the peripheral arteries on the top of the hand's fingers and/or an earlobe using the classic approach of pulso-oxymetry, using the classic formula:
log((**I**tmax/**I**tmin)r / (**I**tmax/**I**tmin)ir) = a * (c1/c2) = a * SatOxygen
The pulsating entity **I** represents the light intensity transmitted on two particular wave lengths (on the red and on the infrared) through the fingers or ears tissue. Basically the sensor has been developed by two light generators (led diodes) and one opto receiver. The saturation value was computed using a special and original digital technique.

SAMPLING FREQUENCIES: The sensors used obviously refer to different physical quantities and different characteristics of the signal to be acquired.
Referring to the pressure sensors, we find that the significant athlete gesture to value has average minimum times of about 200 ms.
An adequate value of scannings to obtain significant information could be about 40 scannings for the period we consider. So that a consistent sampling frequency on each pressure sensors should be 25.6 kHz.
In regard to sensors of acceleration, considering the limitation to 1 kHz brought by the accelerometer, we set the maximum frequency at 750 Hz.
Making a few tests in which the sensor was put in the footwear, we verified that using 250 Hz sampling frequencies the acceleration curve of the foot toward the direction tangent to the foot itself results in superposition with the same curve obtained from a cinematic system (ELITE System).

TRANSFERRING DATA FORMALITY: Because of the specific kind of utilization of the system it has been necessary to introduce different ways or formalities of data transferring from the "holder" to the PC where the data are elaborated.
In particular, it has been necessary to give the system a certain degree of autonomy.

For this reason we introduced the possibility to directly connect the PC by means of a serial cable, for all that activities in which is not necessary for the patient to make singular gestures and the system is close to the PC.
If necessary, an acquisition of a few seconds for a particular gesture (for example a smash in volleyball) - it is possible to acquire it in the internal RAM memory and then to transfer the data via serial cable.
In the case of a longer acquisition it is possible to use a memory-card, through which time of acquisition is in practice unlimited and depends just on the possibility of replacement of the cards.
Two other possible connections were added to these options: by means of a radio module, for short distances (about 100 m) and by means of GSM in the case of remote transmissions.
These two latest options are very useful in the case of acquisitions of long-distance athletic disciplines (marathons, etc. or under severe environmental conditions (tests on skiers, etc.).

RESULTS: The system has been tested in various sports activities using the above-mentioned datalogger interfaced with the described sensors. The tests were performed in cooperation with different work goups: National Research Center (Pisa), Dott. Ceccarelli (MINARDI TEAM), Dott. Uccioli (University of Tor Vergata - Rome), Ing Renato Rodano (Center DON GNOCCHI - Milan), DIADORA Research Center, B.A.T. work group (Treviso). Below are some results of this testing.
MARATHON: An experimental system was applied to an athlete during the Paris Marathon 96 and Venice Marathon 97, and pressures inside the shoes have been measured together with the heart beat. These data have been elaborated a second time and correlations have been found between the increase and decrease in speed and changes in heart beat. The test was also performed with some diabetic athletes.
VOLLEYBALL: Various tests have been executed with volleyball athletes that demonstrated the potential of the system in acquiring data, leaving athletes absolutely free to move. These kind of tests have been done during rehabilitation exercises to check the athlete's recovery after trauma.
RUNNING: A system that can take both pressure inside the shoes and acceleration of the foot during running has been applied to an athlete. This kind of acquisition made it possible to elaborate a statistical algorithm through which it is now possible to obtain an evaluation of the athlete’s speed and the kind of support he makes. Besides, it is possible to evaluate the kind of action made by the athlete’s feet.
F1 CAR RACE: An ECG system has been applied to an F1 car race driver during some races, and the correlation between the different actions of the driver and his heartbeat frequency have been observed. It has been found that it is possible to identify the fatigue condition of the driver by looking at his heartbeat frequency.
Some tests have also been performed on athletes playing golf, riding mountain bikes and playing basketball.

The experimentation proved that the system achieved the aims of the project. It has also been verified that the most critical aspect remains the connection of the sensors.

CONCLUSIONS: The system is at the moment equipped, in standard modality, with a connection to the following sensors: sensors of pressure, acceleration, ECG and opto-sensors. The interface for the EMG sensors is in a phase of definition.

Besides, a new and more ergonomic case is being studied, that better fits the athlete in his sport practice.

We think that in its definitive version this system could be of great interest for diagnostic utilization for athletes and also for the training phase in particular disciplines.