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Aurélien DESCATOIRE[*]; Pierre MORETTO[*]

BARO-PAEDOMETRIC BIOFEEDBACK FOR FOOT UNLOADING PROCEDURES INVESTIGATION

Numerous studies on new biofeedback devices conception development were undertaken. They are used for some compensation methods of the data lost on sensors set. The aim of the study was carried out for introducing several approaches of investigations and testing of the biofeedback devices that support a plantar pressure analysis, for foot unloading processes implementation. The healthy man is walking in normal conditions first; on a walkway. The recorded load on 6 sensors has to be reduced next in a specified area. The pressure was considered at the beginning on metatarsal head, in time of 100 steps. The visual and auditory signals were then adjusted to a specific plantar pressure threshold setting. The peak pressure was evaluated for various walking condition. The introduced device enables us reducing the peak plantar pressure within the appointed risk-regions.

1. INTRODUCTION

The biofeedback analysis devices can provide the user with some encouraging therapeutic procedures. The presented device was satisfactory implemented in specific gait disorders analysis, after its self-regulation processes. The recent development progress was achieved for the measuring device conception development, using several sensors of force and pressure recording, providing the user with new biofeedback interfaces.

The introduced studies have developed plantar biofeedback device able to determine the highest pressure areas and to alert the user by an acoustic alarm unit. It provides both visual and audio feedback in order to correct the plantar pressure distribution, when a local pressure exceeds the determined threshold [1], [2].

The devices are using a signal-warning system that may particularly be appropriate to the patient's disease, suffering from diabetic disorders.

The damaged physiological sensors of the foot can thus be augmented or replaced by external feedback system [3], [4].

In this study some characteristic features of new baro-paedometric feedback devices [5], [6] were introduced. It allows finding the user its individual method for foot unloading method, determining this ability of healthy man recognition without any knowledge of pathology level recognition.

[*] Universite de Lille 2.9, rue de I'Universite, 59790 Ronchin, France

2. THE METHOD IDEAS

Instrumentation set

The Paromed hydro-cell [5] consists of an inbuilt Wheatstone bridge, inserted in a capsule filled-up with liquid silicon, incompressible fluid that produces a pressure map recorded on several carefully selected points on insoles. They represent the forces and stresses in anterio-posterior and medio-lateral foot areas.

Hence, in time of the foot - ground contact, the forces re-actions are recorded in form of the pressure, inside the hydro-cell.

After our calibration processes of the sensors, they enable us to verify sensitivity, linearity and hysteresis of the measurement system. The dynamic forces implementation unit enabled us to calibrate the sensors' set before the gait series are performed.

Peaks of pressure distinguished at the foot print; the RSScan (Olen, Belgium) pressure plate, was used for detection of the peak localisation and to determine the sensors distribution of the customised insole. Two insoles (right and left) were thus prepared comprising 6 Paromed hydro-cells, in each insole, distributed at:

- lateral heel (LH),
- medial heel (MH),
- metatarsal heads 5 (M5), 3 (M3), and 1 (M1),
- the Hallux.

The insoles were supplied by an amplifier and linked with Personal Computer via telemetrically joined data recorder. The metrological process and its experimental feedback (working in real-time mode) was organised for the bio-feedback customised software package, developed under the paper authors supervision.

Feedback facilities

The device records analysis provides the user with simulation interfaces where numerous gait disorders were extracted and classified.

They initiate several new subjects that describe disabilities of patients suffering from diabetic diseases, with their characteristic features recognition and calibration. The visual feedback, which was returned to the subject through two control screens and by video projection, consists of plantar footprint visualisation scenes that correspond with localisation of the insole sensor set (Fig. 1).

The right of the plantar footprint is provided by a scale of colours, from blue, green to red; illustrating intensity of the pressure, at each of the sensors localisation point. A "scorer" was placed on the left side of the foot print, informing the user about the considered performances.

The peak plantar pressure, in physiological conditions (PP_{NC}) was also performed in testing procedures, carried out in time of walking experiments. The peaks of pressure distribution were localised after series of experiments, as so called reference points finding. Each footprint was provided by this reference point then used for putting the diagnosis in relation to this point.

The peak plantar thresholds (PP_{CR}) were placed between 5% and 20% that brings us with: $PP_{CR} = PP_{NC}$ -5% and PP_{NC}-20%.

The reduction of 5% of the Peak pressure would be sufficient to reload the crucial point area, preventing the foot ulceration in its most affected area. This threshold level is

considered as PP_{CRmax} value defined in work [1]. The reduction of 20% of the peak pressure, considered as PP_{CRmin}, enables us to limit excessive relief that result is implemented, in dangerous plantar pressure redistribution [1].

The audio feedback was also implemented as an alarm trigger, combined with the visual feedback. It indicates the local pressure over-load, at the selected area where the PP_{CRmax} was noticed. On the contrary, only the visual feedback informs the subject when the excessive relief occurs.

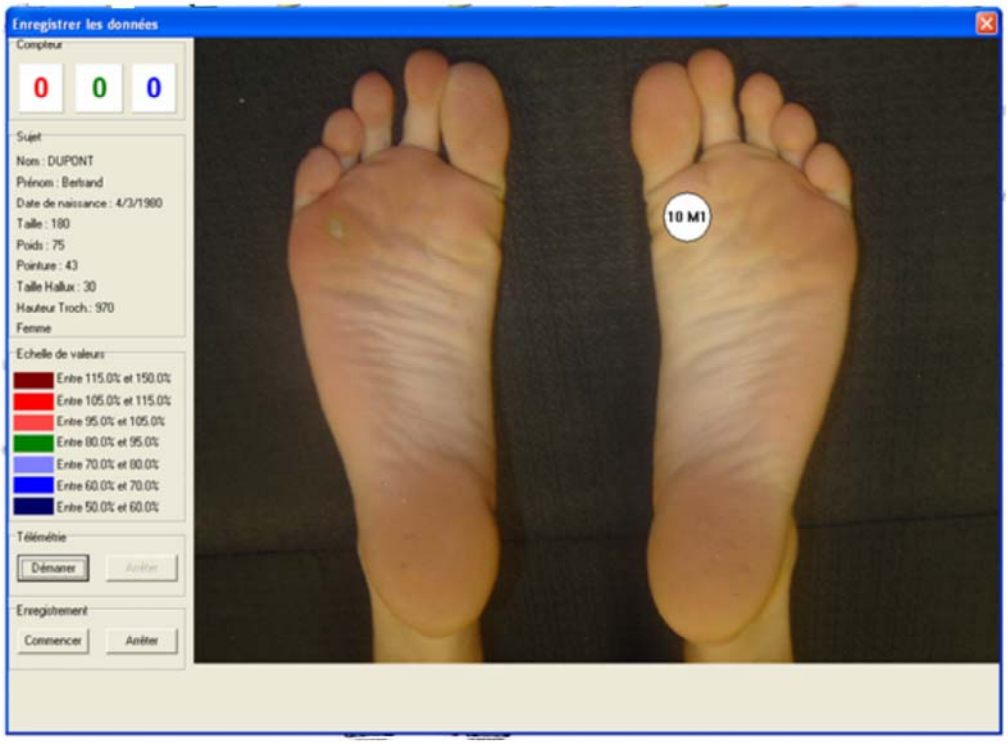

Fig.1. The biofeedback software interface

Each channel could be selected separately to unload the indicated area precisely, returning the feedback under the relevant area. Thus step-to-step, the investigated subject was informed of dynamic events at the foot-ground interface and the remained aware of the overall foot condition.

Walking test

The none-disabled subjects performed the walking tests on a 15 m walkway with possibility of the most suitable walking speed finding. The investigated subject was equipped with two customised insoles and with a belt with telemetric transmission system. It was performed at 15 minutes training session using the discussed device. After that the patient performed the walking test example, for recording the peak plantar pressure distribution in physiological conditions (PP_{NC}); within over 100 consecutive steps, recorded in the diagnostic data records. Then the subject was obliged to relief the first metatarsal region (M1), under the visual and acoustic biofeedback signals analysis. The example unload conditions (PP_{UN}) were applied to the right foot.

3. SOME RESULTS ANALYSIS

The table 1 contains some results recorded after the physiological (normal) and the unloading processes organisation. If the peak pressure is recorded under M1, for the unload conditions fulfilment (between the minimum 20% and the maximum 5% threshold settings) the step performances were considered satisfactory.

In case the peak pressure, recorded under M1, was bigger than PP_{CRmin}, the relief was excessive and the step was considered faulty. For the peak pressure of M1, over the PP_{CRmax}, the relief was insufficient and the step was also considered as faulty.

Recent technologies allow us to modify and optimise existing biofeedback system, in order to develop some additional diagnostics devices; recognised as satisfactory level of the diagnostics device class.

The present case study proved us ability of the diagnostic device development with satisfactory results; in 65% cases, with ability to unload 90% of the steps conditions.

Table 1. Peak Pressure values measured under M1 during the normal and the unload condition

Normal Condition		Unload Condition		
		Success steps $20\%<PP_{UN}<5\%$	Failure steps $PP_{UN}>20\%$	Failure steps $PP_{UN}<5\%$
% of step	-	65	25	10
PP mean	116.7	103.2	75.5	124.8
SD	22	11.8	8.1	5.8
PP min	86.1	87.7	63	116.3
PP max	176.8	110.1	87	133.2

Values given in kilopascals

PP min: minimum of peak pressure, PP max: maximum of peak pressure

4. CONCLUSIONS

In the above discussions one could find our visual and auditory biofeedback solutions, encouraging for diabetic's disorders level analysis by the specific unloads procedure implementation.

The device provides us wit indicators that play valuable role in preventing injuries or ulceration by changing the walking pattern.

The future studies will investigate the use of the device for diagnosis of various disorders of a foot inputs sensitivity studies.

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