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Short communication

Appropriateness of plantar pressure measurement devices: A comparative technical assessment

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ABSTRACT

Accurate plantar pressure measurements are mandatory in both clinical and research contexts. Differences in accuracy, precision and reliability of the available devices have prevented so far the onset of standardization processes or the definition of reliable reference datasets. In order to comparatively assess the appropriateness of the most used pressure measurement devices (PMD) on-the-market, in 2006 the Institute the author is working for approved a two-year scientific project aimed to design, validate and implement dedicated testing methods for both in-factory and on-the field assessment. A first testing phase was also performed which finished in December 2008. Five commercial PMDs using different technologies—resistive, elastomer-based capacitive, air-based capacitive—were assessed and compared with respect to absolute pressure measurements, hysteresis, creep and COP estimation. The static and dynamic pressure tests showed very high accuracy of capacitive, elastomer-based technology (RMSE < 0.5%), and quite a good performance of capacitive, air-based technology (RMSE < 5%). High accuracy was also found for the resistive technology by TEKSCAN (RMSE < 2.5%), even though a complex ad hoc calibration was necessary.

1. Introduction

Even today plantar pressure measurement is hardly considered a meaningful tool in clinics or in research contexts, although its potential is highly recognized [1]. Reasons for such poor success may be searched in different accuracy and reliability of existing pressure measurement devices (PMDs) due to different sensor technology, spatial resolution, pressure range, sampling rate, calibration and processing procedures. Very few technical studies have been published until now on this issue [2–5], and no peer-reviewed studies have been found about technical assessment and comparison of different PMDs.

To overcome this need, in 2006 the Institute the author is working for approved a two-year project to design, validate and implement dedicated testing methods and instruments for PMD technical assessment with respect to accuracy and reliability of measured pressure, hysteresis, accuracy and precision of centre of pressure (COP) estimation. Once instrumentation and procedures had been implemented and validated, Companies were officially invited to take part in the study to assess their best product on the market. The testing phase finished in December 2008. Five PMDs were tested in all: three had resistive sensors (TEKSCAN, RSSCAN, MEDILOGIC, all taken from the market), one had capacitive elastomer sensors (NOVEL, delivered by the Company), one had capacitive air sensors (AM CUBE, delivered by the Company). The study reports on the testing equipment and protocols, and on the main results of the technical assessment of the above products.

2. Materials and methods

Two testing devices were constructed and validated (Fig. 1): a custom pneumatic bladder pressure tester (PM) and a dedicated pneumatic-force testing device (PTD).

The PM, used to uniformly apply pressure over the entire PMD sensor matrix, is a very heavy structure with a membrane interfacing the inflated air and the PMD surface. It was used together with a digital pressure transducer (resolution 10 Pa) to deliver pressure ramps of loading from 0 to the maximum declared PMD pressure (1200 kPa at maximum) and back to 0, with 50 kPa steps, between-step transition time 5 s, step duration 5 s.

The PTD – widely described elsewhere [6] – consists of a pneumatic testing device with an on-off valve, a proportional valve, force and pressure controls (relative error <1%). Pressure is applied through a stainless steel head (7.03 cm^2, no membrane in between). Applied pressure ranges from 0 to 600 kPa. For each PMD, the following tests were performed over 5 randomly selected areas:

(1) 100 kPa steps of static pressure from 0 to 600 kPa and back to 0, each step lasting 5 s, the area being completely offloaded after each step;
(2) sinusoidal pressure cycles (0–500 kPa; 0.75 Hz; at least 10 cycles) applied through the proportional valve;
(3) constant pressure (350 kPa; 60 s) to investigate creep.

To assess COP estimation an additional tool was constructed to apply known forces through the PTD, whose core is a graduated aluminium table, 15 cm diameter, with three 3 cm-diameter pylons, and a central hole to vertically insert a pin and acquire the theoretical COP coordinates. For each area, COP measurements were performed at a fixed load under 6 different angular positions (angular step 20°).

Raw data, acquired at 20 Hz for the sinusoidal test and at 5 Hz for all the remaining tests, were processed as follows:

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