COMPARATIVE EVALUATION OF PRESSURE MAPPING SYSTEMS (1): BENCH TESTING RESULTS

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ABSTRACT

In order to help seating practitioners assess the seated posture and pressure distribution needs of wheelchair users there are a variety of real-time objective pressure mapping devices available. It is imperative that the performance of these devices is known in order that results can be interpreted correctly and results from using different systems may be comparative. In this paper, we have bench tested three pressure mapping devices from Tekscan, Xsensor and FSA providing data on hysteresis, reproducibility, creep and rate of response. The results show that the performance of pressure mapping systems has improved since a report in 1993 by Ferguson-Pell and Cardi and that there is little to choose between them based on these test results. This work is ongoing as part of an ISO standard for wheelchair seating. Further tests are in progress to establish performance using contoured loading strategies and these will be presented separately.

BACKGROUND

Over the past several decades wheelchair manufacturers have been providing an increasing variety of seating products that provide improved body support and injury prevention for the wheelchair user. In order to help seating practitioners arrive at a solution appropriate to the needs of the wheelchair user there has also been an increase in the variety of measurement devices available to give real time communication of anthropometric measures and interface pressure distribution. It is imperative that the performance of these devices is stated allowing the seating practitioner and manufacturer to interpret results, understand their limitations and compare performance between different systems.

In 1993 a study was carried out by Ferguson-Pell and Cardi (1) on the performance of wheelchair pressure mapping systems available at that time. Since then technology, fabrication methods and materials available for their development has improved and software programming techniques have advanced. This has allowed some of the findings of that study to be addressed with the improvement and introduction of new pressure mapping systems. As pressure mapping techniques are being used increasingly in the clinical setting for prescription of wheelchair cushions it is timely that their performance should be re-evaluated and compared.

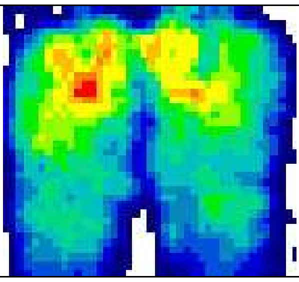
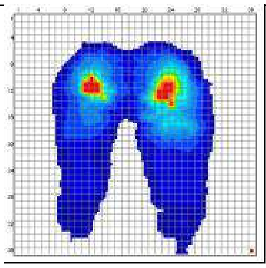
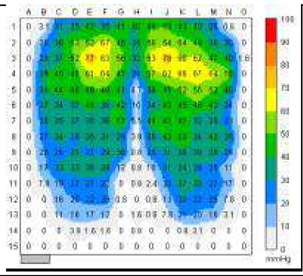
This work is being completed as part of the development of an ISO (International Organization for Standardization) standard in wheelchair seating. It is being prepared as part of Technical Committee TC 173 " Technical Systems and Aids for Disabled or Handicapped Persons", Sub committee SC-1-Wheelchairs, Working Group WG-11-Wheelchair seating. This involves bench tests to determine accuracy, hysteresis, repeatability/reproducibility, stability, creep, rate of loading response and mat artifacts (i.e. effect of mat on applied load shape, effect of drape such as kinking and hammocking), environmental effects, calibration stability and contoured loading performance.

RESEARCH QUESTION

The objective of this study was to determine the performance characteristics of three types of pressure mapping systems, providing information on hysteresis, repeatability, stability/creep and rate of loading response.

METHOD

Equipment

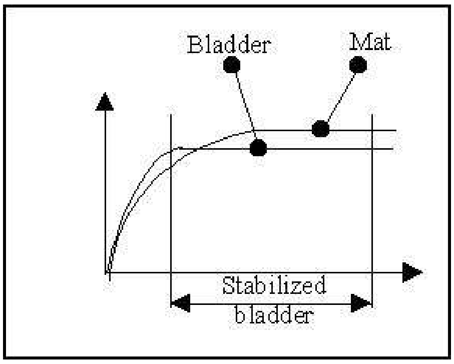
System	Tekscan	Xsensor	FSA
Manufacturer	Tekscan Inc. Boston. US	Xsensor Technology Corporation, Calgary, Canada	Vista Medical, Winnipeg, Canada
			
Sensor type	Conductive ink	Capacitive	Conductive rubber
Single sensor area	103 mm^2	135 mm^2	298 mm^2
Sensor pitch	10 mm	13 mm	25 mm
Number sensors	1558	1296	225

Bench tests

Calibration. Each pressure mapper was calibrated according to the manufacturer's instructions using the FSA calibration apparatus with the mapper and air bladder sandwiched between two wooden platens.

Hysteresis and repeatability. Planar loads were applied in increments of 20 mmHg from 0-200-0mmHg. The loading rate was one 20 mm Hg increment every 10 seconds with a 10 second delay at each increment. The tests were repeated twelve times removing and reinserting the pressure map between each repetition. Output measurements for each loading cycle were recorded and hysteresis was disclosed by measuring the difference between ascending and descending traces at 50, 100 and 150 mmHg. Repeatability was disclosed as the coefficient of variation for the readings obtained at 50, 100 and 150 mm Hg in the 12 tests.

Stability/creep and rate of response. Pressure was applied by ramping to 100 mmHg in 10 seconds without overshoot and constantly applied for ten minutes. A continuous electronic recording of the applied pressure and output readings was taken at a sampling rate of 1 frame/second. Stability was disclosed by expressing the change in output after 10 minutes of stabilization from the instant the applied pressure level was reached. Rate of response was disclosed as the ratio of the response time of the bladder pressure to the pressure mapping system to reach 100 mmHg.



RESULTS

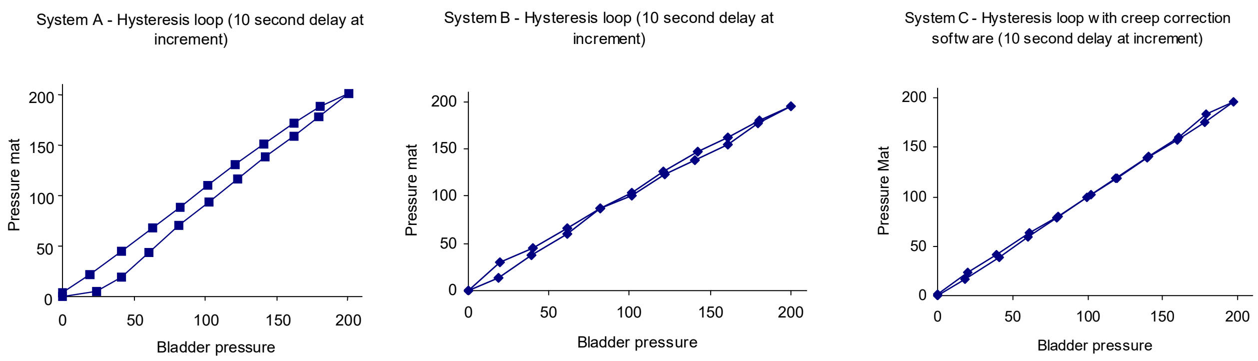


Figure 1. Hysteresis curves for A) Tekscan, B) Xsensor and C) FSA.

Table. Summary of bench test results

Parameter		Tekscan	Xsensor	FSA
Hysteresis	50 mmHg	24.6 mmHg	5.6 mmHg	3.5 mmHg
	100 mmHg	17.3 mmHg	3.1 mmHg	0.6 mmHg
	150 mmHg	12.2 mmHg	7.5 mmHg	5.8 mmHg
Repeatability	50 mmHg	14.2 %	4.0 %	1.8 %
	100 mmHg	3.0 %	2.8 %	1.8 %
	150 mmHg	0.9 %	1.3 %	1.7 %
Stability/creep	100 mmHg	20 mmHg	2.8 mmHg	1.8 mmHg
Response time	0-100 mmHg	0.5	0.4	1.0

DISCUSSION

These bench test results demonstrate how current pressure mapping systems show smaller hysteresis and creep values than marred earlier versions and made practitioners and researchers wary of using them. The Xsensor and FSA have hysteresis at 100 and 150 mmHg < 5 % with repeatability < 4 %. The FSA exhibits < 2% creep over 10 minutes at 100 mmHg. The Tekscan showed higher hysteresis and creep values and these results are being investigated with respect to the calibration rig used; the system was shown to have much better performance using a smaller air bladder (results not shown). The manufacturers suggest air entrapment within the sensor may be responsible for the performance observed. This highlights the need to adopt correct bench tests to adequately assess performance and work is ongoing to define standard test methods for incorporation as an informative annex in the ISO standard. These results provide basic information on pressure mapper performance. In order to assess the performance of these pressure mapping systems in a more applied manner, tests are being conducted using soft contoured loading indentors and these results will be presented separately.

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COMPARATIVE EVALUATION OF PRESSURE MAPPING SYSTEMS (2): CUSHION TESTING

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ABSTRACT

The availability of a number of pressure mapping product raises the concern that different results may be obtained from different mapping systems. This has implications for both clinical decision making, and the disclosure of seating system performance characteristics by cushion manufacturers. In Part 1 of this series of abstracts we discussed the performance of pressure mapping systems subjected to highly controlled bench tests using a calibration rig. In this part the cushions were tested under loading conditions designed to simulate normal use. Each of the pressure mapping systems were loaded using a cushion loading indentor (Gelbutt, Beneficial Design, Santa Cruz, USA) on a range of different wheelchair cushions. The results indicate that when the pressure values are summed and multiplied by the active sensor area (measurement of the applied force) the three pressure mapping systems tested indicate an applied force that is within 10% of the known applied force for the range of cushions tested.

BACKGROUND

In 1993 a study was carried out by Ferguson-Pell and Cardi (1) doubts were raised as to whether pressure mapping systems could rank a set of cushions in the same order, let alone provide reliable quantitative information about them. The difficulties they experienced could have been a consequence of using human subjects to load the cushions. Poor repeatability of human subject tests has been reported (3) and therefore reduces statistical confidence in comparing the results. The use of buttock shaped indentors (1,2,3,4,5) offers an opportunity to improve the repeatability of these tests and compare the performance of the different pressure mapping systems.

This work is being completed as part of the development of an ISO (International Organization for Standardization) standard in wheelchair seating. It is being prepared as part of Technical Committee TC 173 " Technical Systems and Aids for Disabled or Handicapped Persons", Sub committee SC-1-Wheelchairs, Working Group WG-11-Wheelchair seating.

RESEARCH QUESTION

The objective of this study was to compare the results obtained from three pressure mappping systems (Tekscan Inc. Boston US; Xsensor Technology, Calgary Canada; FSA, Vistamedical Winnipeg Canada) when loaded using the Gelbutt on a range of pressure mapping sytems. These initial tests sought to determine whether current pressure mapping systems could accurately indicate the total applied force for a wide range of cushion types.

METHOD

The Gelbutt consists of a buttock shaped undersurface fabricated using a proprietary mix of urethane gel. A replica human pelvis is positioned within the gel to produce loading distributions similar those produced by human subjects. The top surface of the Gelbutt is a rigid plate marked with a central datum. In order to use the Gelbutt it is necessary to fabricate a loading rig to apply the indentor section with known loads and with the orientation of the Gelbutt relative to the cushion carefully controlled. A simple rig was fabricated using a bi-directional pneumatic piston and a metal frame (see Figure 1).

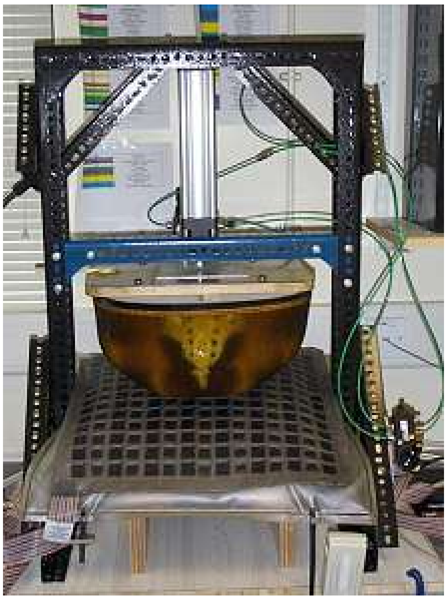


Figure 1. Gelbutt and loading rig prepared for loading. An airbladder (used in ISO tests for inter-center comparision) is in position with an AF FSA pressure mapping system placed on top.

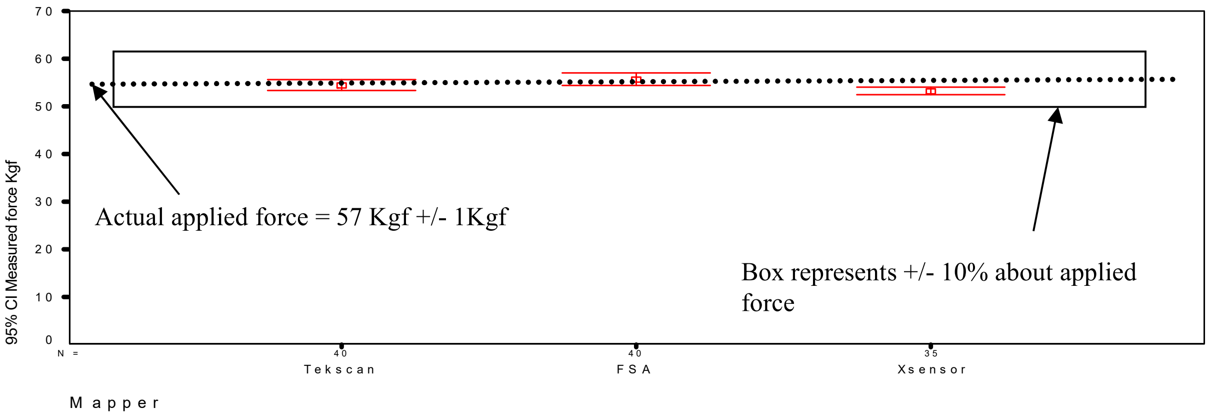
For these tests the Gelbutt was fixed in a horizontal position relative to the support for the cushion. A total load of 570N (including the weight of the Gelbutt) was applied to each cushion tested. All the pressure mapping systems were calibrated up to 200 mmHg according to the manufacturer's specifications using the FSA calibration rig which employs an airbladder inflated between two fixed plywood platens. The applied load was determined by placing a calibrated scale (similar to bathroom scale) under the Gelbutt. Air pressure controlled by a regulator was applied to the piston until the scale reached the required load. The required pressure was noted and repeatability tests performed. The applied load was noted to remain within 250g of the specified load yielding a variation of less than +/- 0.5%). The repeatability of the Gelbutt loading system was tested by loading a Tekscan system on an inflated air bladder. The peak pressure under the ischium (left) was selected as an anatomically meaningful site. The peak pressure parameter was chosen since it is sensitive to small variations.

A range of 8 cushions was selected. Each cushion was new when tested and was preconditioned by applying 2 cycles of uniform load at 850N. The pressure mapper was then placed on top of the cushion and the Gelbutt applied rapidly at the prescribed load for 60s. The load was then removed rapidly and the system allowed to relax for 60s before repeating the cycle of loading and unloading 5 times for each pressure mapping system.

The results were analyzed by summing the pressure readings and multiplying by the active area of the sensor (or using the total force value presented by the software where available) after 60s of loading for each pressure mapper and cushion combination.

RESULTS

The variation in peak pressure for 5 repetitions using the Tekscan sensor on an air bladder was 83-86 mm Hg (excluding 1 outlier). The mean was 83.6 mm Hg (s.d. 3.4) and range was 78-86.



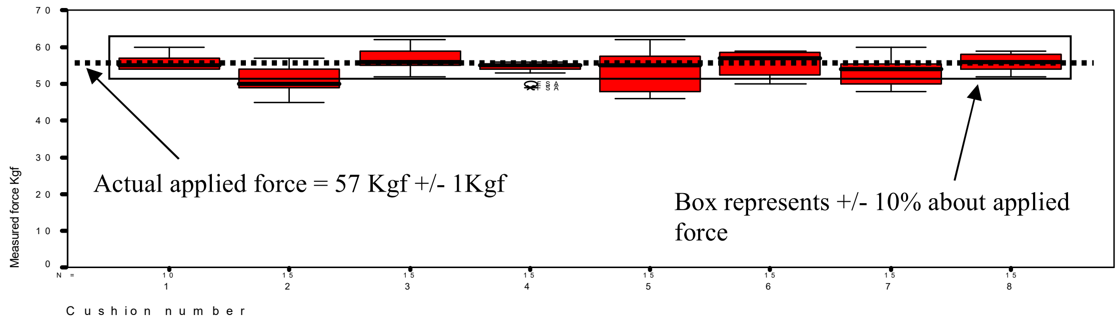


Figure 2. Results combined for all cushions indicating the variation for each pressure mapper in measuring the applied force of 570N

Figure 3. Results combined for all pressure mapping systems indicating the variation in measuring the applied force of 570N for each cushion.

DISCUSSION

These results are a preliminary and encouraging indication that the three pressure mapping systems are able to generate data that is comparable across systems for a wide range of wheelchair cushion types. They also indicate that the pressure mapping systems accurately measure the applied force, again independent of cushion type. These results were obtained with a replica shape of the human buttocks with nominally comparable mechanical properties. It is reasonable to assume that human buttocks that fall within the nominal shape and mechanical characteristics of the Gelbutt would produce comparable results. However it is not safe to *assume* that subjects with very emaciated buttock tissues would produce similar results.

The loading system used was shown to produce repeatable loading conditions when tests were performed on an air bladder. The variation observed was within the anticipated repeatability of the Tekscan pressure mapping system used for the test.

Regardless of the cushion type tested, the pressure mapping systems yielded a calculated total force well within +/-10% of the applied force. This offers an opportunity for standard test methods using pressure measurement to require that the total applied force obtained for the test be disclosed along with other parameters. Should this value fall outside these limits the readings should be considered invalid. The results also indicate that the variability is dependent upon the cushion tested, suggesting that either the pressure mapping systems or the test rig are less repeatable for certain cushion types. The reasons for this variation require further investigation.

These results only consider the variation of one simple parameter according to mapper or cushion used. Further analysis is required to determine whether substantial variations in parameters such as peak pressure, contact area and average pressure occur between mappers and cushions.

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