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Pressure mapping and subjective evaluation of comfort of 15 selected pressure relieving seat cushions

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TITLE

PRESSURE MAPPING AND SUBJECTIVE EVALUATION OF COMFORT OF 15 SELECTED PRESSURE RELIEVING SEAT CUSHIONS

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ABSTRACT

The aim of this study was to establish an overview over pressure relieving and pressure distributing properties of a selection of seat cushions available in the Norwegian market, and to document level of discomfort for persons seated in the same static position for a longer period of time. 15 subjects participated in the study. Pressure data was collected over a continuos period of 90 minutes. Subjects were asked to respond to seven statements related to their subjective feeling of sitting comfort, starting at the 10th minute, with 20 minute intervals thereafter.

Subjects reported extensive discomfort after 90 minutes. None of the cushions lost their carrying capacity or resilience during the test period. Nevertheless, pressure values and distribution varied considerably. This underlines the fact that choice of seat cushion should always be considered as highly individual and dependent on multiple factors.

KEYWORDS	ENGLISH	NORWEGIAN
GROUP 1	Health	Helse
GROUP 2.	Technical aids	Tekniske hjelpemidler
SELECTED BY AUTHOR	Pressure relieving seat cushions	Trykkavlastende sitteputer
	Pressure mapping	Trykkmåling
	Subjective comfort	Subjektiv komfort

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1 BACKGROUND

Pressure ulcers represent a dominant health problem for persons who, for various reasons, are bound to spend most of their time in a seated position. More than 200 causes have been identified as contributing to the development of pressure ulcers [1]. These can be categorised into external and internal factors [2,3]. Among the external causes, pressure related to time is believed to be the most significant. When the interface pressure exceeds the mean pressure in the capillary veins, the veins tend to collapse. If such a situation is maintained over a longer period of time, ischemic necrosis will develop in the affected area [4,5]. In addition to this main cause, other external factors are believed to enhance damage development. Most acknowledged are shear stress, increased skin temperature and humidity [2,6,7,8,9,10]. Internal causes frequently cited are age, physical condition, degree of mobility, sitting posture, quality of skin and tissue, reduced sensibility, incontinence, and nutrition [2,11].

Due to the enormous costs stemming from treatment of pressure ulcers, it seems clear that prevention would be beneficial over treatment [1]. Seat cushions are important in this regard [12]. A seat cushion should contribute to a functional and balanced posture. In addition, it should reduce the level of pressure by distributing pressure from critical areas (like the sacrum and ischial tuberosities) to more tolerant areas, and by distributing pressure over a larger contact area [13]. However, the amount of valid and reliable scientific documentation on the effectiveness of the products existing in this market is limited [14]. Despite the fact that persons engaged in the field seem to agree that no seat cushion is best suited for all categories of patients, but rather must be selected individually to meet these demands, there are no existing common guidelines for seat cushion selection [15, 16]. At present, cushions are chosen on the basis of affordability, availability, and experience based judgements of the therapist involved rather than on scientific data [5].

The purpose of this study was to establish an overview over pressure-relieving and pressure-distributing properties of a selection of seat cushions available in the Norwegian market. In addition, there was a need for documentation on the subjective experience of discomfort as experienced by people when subjected to sit in the same static position for longer periods of time. The aim was, therefore, *not* to judge any product or product material to be the overall 'best' or 'worst', but to provide objective, comparable data that may contribute to enhanced knowledge and to improve the level of competence among practitioners and others working with pressure-reliving products.

The project was launched in January 2003, and is financed by The National Insurance Administration (Rikstrygdeverket), eight different Norwegian manufacturers/distributors[1] and SINTEF Unimed. SINTEF Applied Mathematics has contributed in the data analysis.

[1] Participating manufacturers/distributors: Alu Rehab AS, Care Product AS, Etac AS, HandiCare ASA, Invacare AS, Møller Vital AS, Sunrise Medical AS, Tempur AS.

2 METHODS AND DATA COLLECTION

2.1 Equipment

Data was collected with a pressure-mapping mat of the type Force Sensitive Applications (FSA). The FSA system provides detailed mapping of the interface pressure between the contact surface of a person and the support surface he/she is sitting, lying or standing on. The FSA mat consists of 32x32 thin, 1 cm^2 flexible piezo-resistive sensors.

The measurements were gathered for a period of about 90 minutes. The average data set was about 24000 samples. Each sensor has a resolution of 8-bits (256 possible values) linearly spaced between the values 0 and 200.

The FSA-software stores the data of each experiment in a binary file. The software itself has limited export features, so a FSA-fileformat converter was written to analyse the data. A small program was written to calculate distributions, which were visualised in Microsoft Excel. In addition the exported data were analysed in Unscrambler (statistical analysis package).

2.2 Protocol

2.2.1 Pressure mapping

All recordings took place in the same laboratory. The temperature in the room was kept at 20 °C. All subjects were placed in a wheelchair of type Handivipp. A standardised position was assured by defining the following joint angles when seated:

- Hip angle: 110°
- Knee angle: 105°
- Ankle angle: 90°

The back and tilt function of the chair was regulated to the preferred hip angle before tests started, and were not changed throughout the test period of 6 weeks. Position was adjusted for each subject solely by vertical regulation of the footrest plates, to assure accurate knee angle. The footrest plates were locked in a position defining a 90° ankle angle.

Figure 1a and b : Illustrations of the experimental set-up and adjustment of seated position

Before recordings started, each cushion was pre-shaped by the test person for a period of 15 minutes. All air-filled cushions were adjusted by an experienced occupational therapist, in line with the instruction manual. The FSA mat was placed on top of each seat cushion. Before starting recording,

the test leader evaluated the placement of the mat by using the online Scan-function in the FSA-system. If any part of the contact surface was not satisfactorily mapped, subjects were repositioned and checked again, until positioning was adequate. Other disturbances, like folds in the pressure mat or different weight bearing on the thighs, were also double-checked before start of each recording. Each subject was also asked whether they needed to go to the bathroom, before the recording started.

After assuring correct positioning in the chair, and before each recording started, each subject was instructed to sit as still as possible, with their hands on their lap. They were told not to move their feet, and not to turn their head – unless it was absolutely necessary. If some subjects sneezed, coughed etc., the time and type of incident was noted in the protocol.

If any of the subjects during the test felt uncomfortable or in pain to such a degree that she felt that she was forced to discontinue the test, the time was noted and the subject was then allowed to change position by leaning on the armrests, thus relieving pressure on the seat. Afterwards, the subject was told to try again. If the subject still did not feel capable of finishing the test, the recording was stopped. Time and cause for termination was then noted.

2.2.2 Subjective experiences of comfort

Starting at the 10th minute and with 20-minute intervals thereafter, the subjects were asked to respond to seven statements related to their subjective feeling of sitting comfort. Subjects were asked to state whether they agreed or disagreed to the statements presented on a scale from 1 - 5. The test leader informed subjects that this would be part of the procedure before recording started. The protocol for the data collection of subjective experiences of comfort is found in appendix 1.

2.3 Subjects

15 female subjects participated in the study. None of the subjects were wheelchair users. The reasoning behind this was twofold. First, participation in the study demanded each subject to be seated in the same, static position for a period of 90 minutes on six different cushions. To ask a person with muscular atrophy, reduced circulation and/or sensibility, problems with incontinence and the like, to remain seated in the same position for such a long period of time, would imply considerable risk for actual development of skin changes and, in the worst case, pressure ulcers. Thus, from an ethical point of view, we found it unacceptable to recruit real wheelchair users to participate in the study. Secondly, when aiming to reveal differences between different *products*, rather than persons, it is a necessity to create a homogeneous test group. Ferguson-Pell & Cardi [8] emphasise the importance of using real wheelchair users as subjects, since the pressure distribution generated by a person with atrophied tissue and bony prominences will differ from that generated by non-disabled subjects. However, the variance will be larger within a group of wheelchair users, since the level of atrophy and eventual physical deformities will be highly individual [18, 19], and therefore problematic to categorise into large homogenous groups. Thus, studies including just a small number of participants, will have a questionable reliability. On the other hand, using non-disabled subjects will endanger the validity if the aim is to establish an acceptance level for pressure relieving effects. In this study we chose to use subjects that were not wheelchair-users. This implies that the results cannot be generalised to all wheelchair users.

All participants signed an informed consent before joining the study.

Background information on the participants is revealed in Table 1.

Table 1: Age and anthropometric measures of the participants

Subject	Age	Height	Weight	Body Mass Index (BMI)
01	50	173	63	21.0
02	44	171	57	19.5*
03	29	174	67	22.1
04	23	171	64	21.9
05	25	160	58	22.7
06	43	178	65	20.5
07	21	179	59	18.4*
08	26	167	59	21.2
09	22	167	60	21.5
10	30	168	62	22.0
11	57	164	58	21.6
12	17	168	56	19.8*
13	50	173	63	21.0
14	30	174	67	22.1
15	44	171	57	19.5*
Average	*34*	*170.5*	*61*	*21.0*

The BMI-scale describes a person's weight in relation to their height, and is thus a more valid measure than isolated weight to reveal whether a person is underweight, normal weight or overweight. The scale is interpreted as follows:

< 20 Underweight
20-24.9 Normal weight
25-26.9 Slightly overweight
27-29.9 Overweight
30< Obesity

The subjects participating in this study had a BMI ranging from 18.4 to 22.7. They were, in other words, either categorised as underweight (n=4) or in the lower scale of normal weight (n=11).

2.4 Cushions

Each contributor was given the opportunity to participate with one or two cushions. Table 2 shows the selection of cushions included in the test.

Table 2: Cushions included in the test

Manufacturer/ distributor	Name of product	Materials	Recommended use
Alu Rehab	Vital Base Active	Cushion: Polyurethane-foam Cover: Polyester, cotton, acrylic, polyurethane	Seating cushion for medium risk users Best results in wheelchairs with a flat stable platform for cushions, and where users don't require particular side support in cushion. Typical use: In all-round-wheelchairs with flat cushion base
Alu Rehab	Vital Base Royal	Cushion: Polyurethane-foam, polyurethane-gel Cover: Polyester, cotton, acrylic, polyurethane	Seating cushion for high risk users Best results in wheelchairs with a flat stable platform for cushions, and where users benefit from side support in cushion. Typical use: In comfort-wheelchairs with flat cushion base
Care Products	Caresit MFE 600	Cushion: Soft PVC with rubber (air) Cover: Trevira CS (PES)	Used by persons sitting on normal chairs and wheelchairs with a medium to high risk for getting pressure sore.
Care Products	Caresit MFE 601 split	Soft PVC with rubber (air) Cover: Trevira CS (PES)	Used by persons sitting on normal chairs and wheelchairs with a medium to high risk for getting pressure sore.
ETAC	ROHO Quadtro Select	Cushion: Neoprene rubber / Air Cover: Nylonlycra	All individuals who are at high risk of skin breakdown or need healing of pressure ulcers (also surgical wounds). Useful for positioning.
ETAC	ROHO Nexus Spirit	Cushion: Neoprene rubber / Air Foam base: Polyrethane Cover: Nylonlycra	Individuals in a high risk of skin breakdown, combined with the need of increased stability.
HandiCare	Smart Sit 1	Cushion: Polyurethane, expanded Ventilation mat: Polyester fibre Cover: Polyester fibre	Persons with low/medium risk of getting pressure sores may use this cushion. Persons with a high risk of getting pressure sores should not use this cushion.
HandiCare	Smart Sit 2	Cushion: Polyurethane, expanded Visco-elastic insert:Polyurethane, expanded with visco-elasticity Ventilation mat: Polyester fibre Cover: Polyester fibre	Persons with low/medium risk of getting pressure sores may use this cushion. Persons with a high risk of getting pressure sores should not use this cushion.
Invacare	Kineris HP	Cushion: Air (Neoprene) Cover: Polyester, Polyurethane	High risk users, pressure sores stage 1-3
Invacare	Infinity Airflow	Cushion: High resilient foam and Air (Neoprene) Cover: Polyester, Spandex, Polyurethane	High risk users, pressure sores stage 1-3, stabilisation/positioning needs
Møller Vital	Vicair Academy Adjuster 10	Inner cover and cells : Nylon fabric coated with polyurethane / Polythene (air)	Persons in the medium to high risk category.
Møller Vital	Vicair Positioner Plus 10	Inner cover and cells : Nylon fabric coated with polyurethane / Polythene (air)	Persons in the medium to high risk category.
Sunrise Medical	Jay 2 Deep Contour	Cushion: Polyethylene foam, JF35 fluid and urethane foam. Cover: Air/nylon/polyester	Persons with high risk of getting pressure sores.
Sunrise Medical	Jay Triad	Cushion: Polyethylene foam, polyurethane foam, viscoelastic foam, urethane film on the top surface. Cover: Polyester	Persons with medium risk of getting pressure sores.
Tempur	Tempur MED	Cushion:Visco-elastic polyurethane foam Cover: Polyester/Cotton	Patients and clients in the medium to high risk category of getting pressure sores.

Table 2 is based on information provided by the manufactors/distributors. More information on each product may be found by browsing the webpages of each manufacturor/distributor. All webpage adresses are available in appendix 2.

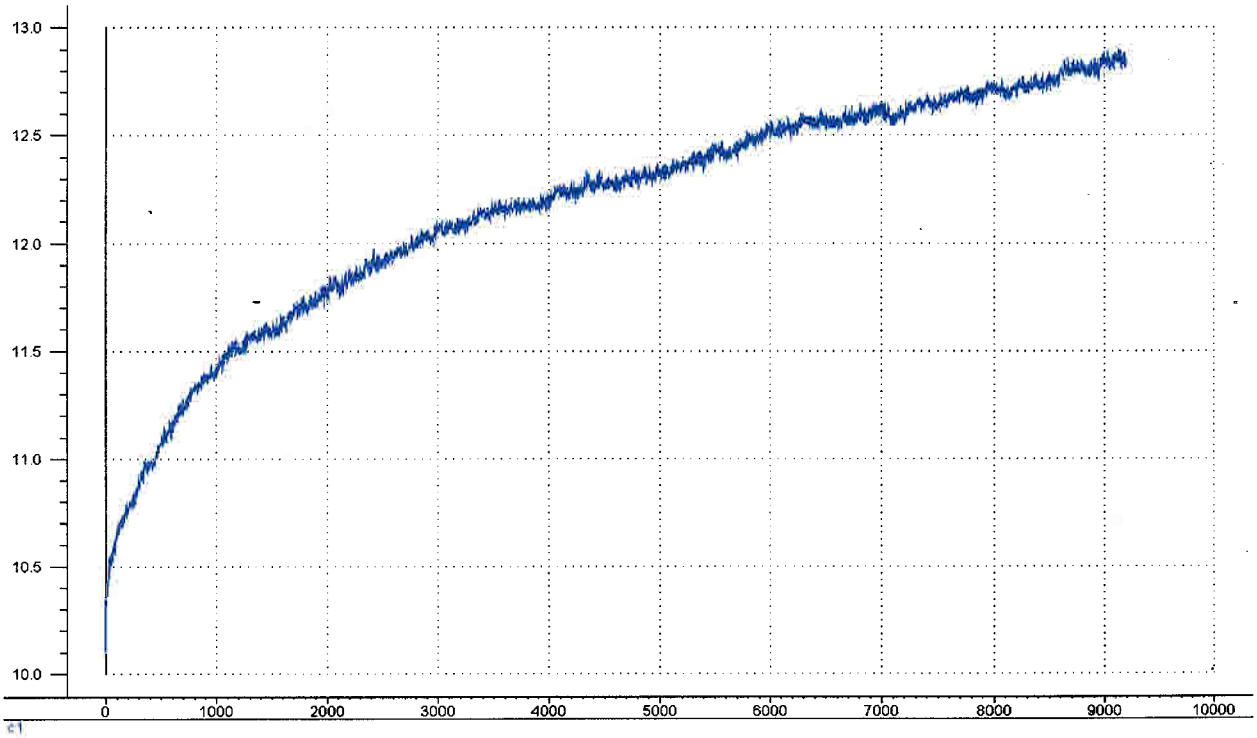
2.5 Methodological challenges

Pressure mapping systems provide knowledge about pressure distribution, peak and average values, through measurements recorded when the sensor mat is placed between the seat surface and the users' buttocks [15]. Despite increasing use of such systems, there are today no standard methodological guidelines for pressure measurement. Different producers and distributors as well as researchers approach the issue with dissimilar measurement equipment. Taken separately, many studies may be valid and reliable, but due to the use of different and incomparable equipment they are difficult to compare and thus of limited external validity [2,4,14,17].

It is important to keep in mind the limitations of this study as well. Introducing an object between the person and the seat surface will in itself affect the pressure distribution and shear stress to some degree, even if it is only a thin, flexible pressure-mat. It is, at present, not well documented whether the effect is the same or different on diverse materials, i.e., whether measurements on some cushions may be affected more than others. This is an aspect that should be further investigated in later studies.

During the test-period, it was observed that the pressure measured was increasing with time. It was believed that this was mainly due to an instrumental effect and a small study to test this phenomenon was done. Firstly, a box filled with books (about 8 kg) were placed on a hard surface, with the sensor-array in between. 10000 measurements were recorded and the following development in the mean values of the active sensors was calculated. By 'active sensors' we mean the sensors covered by the box, and thus having values larger than zero.

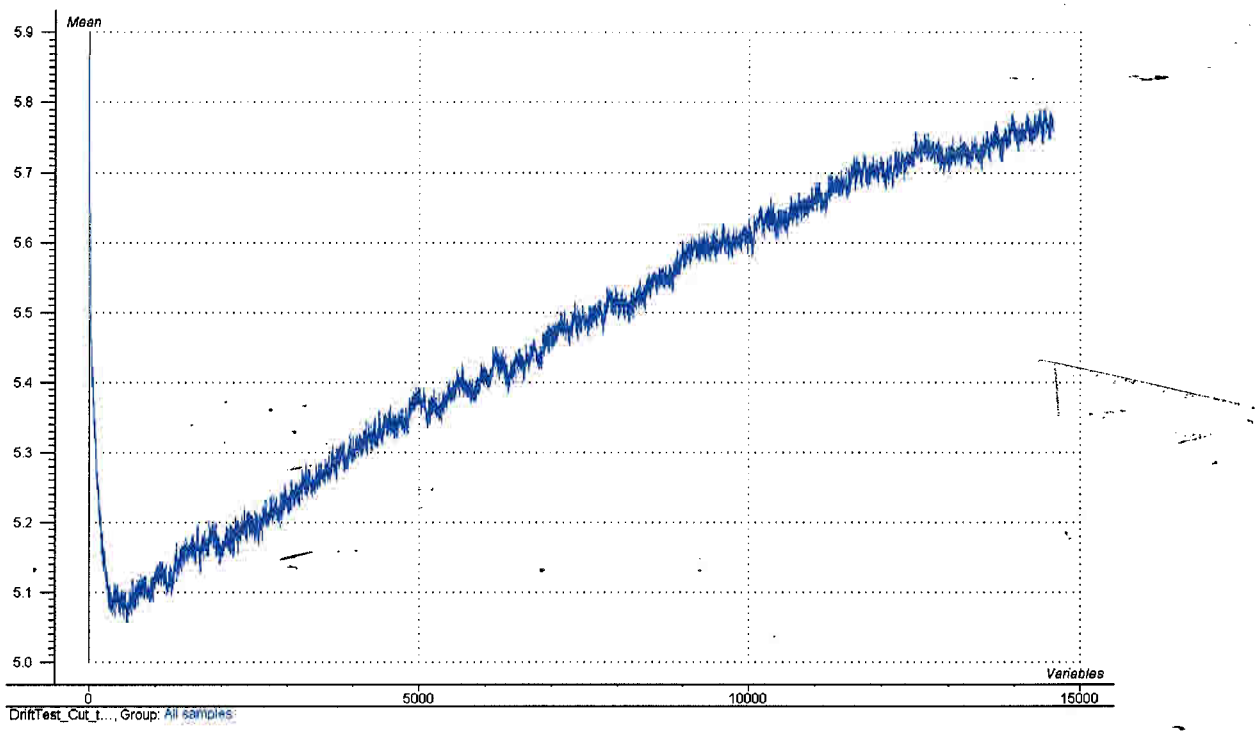
Figure 2: 8 kg load on a hard surface



There is a 25% increase in the mean values from start to end.

Secondly, the same experiment was repeated, but this time with a seat cushion between the sensor-array and the box. The development in the mean values of the active sensors was recorded and is visualised below.

Figure 3: 8 kg load on a seat cushion

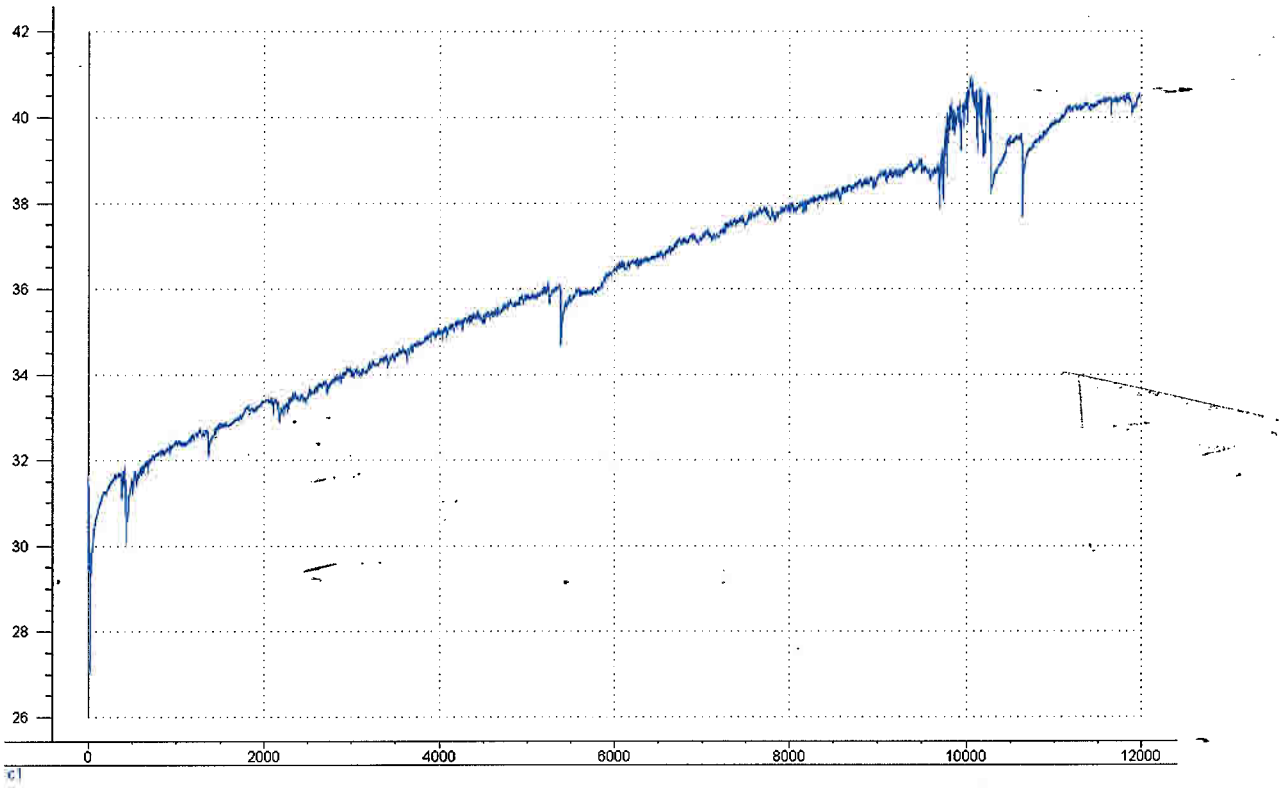


15000 samples were recorded this time. During the first minute, the seat cushion stabilised the pressure until the minimum values were reached. Over the next 10000 samples, the mean value increased only about 10% compared to the 25% increase without the use of a cushion. Actual values were also considerably lower with the use of the seat cushion. This is due to the fact that the number of active sensors is approximately 50% higher with the cushion than without, because the pressure is spread out over a larger area.

After the first 5 minutes (approximately 1000-1500 samples), the shapes of the two curves are about the same. Thus, the sensor-array and measurement equipment use a few minutes to get stabilised and then the increase in the magnitude of the measurements seems to come entirely from instrumental drift.

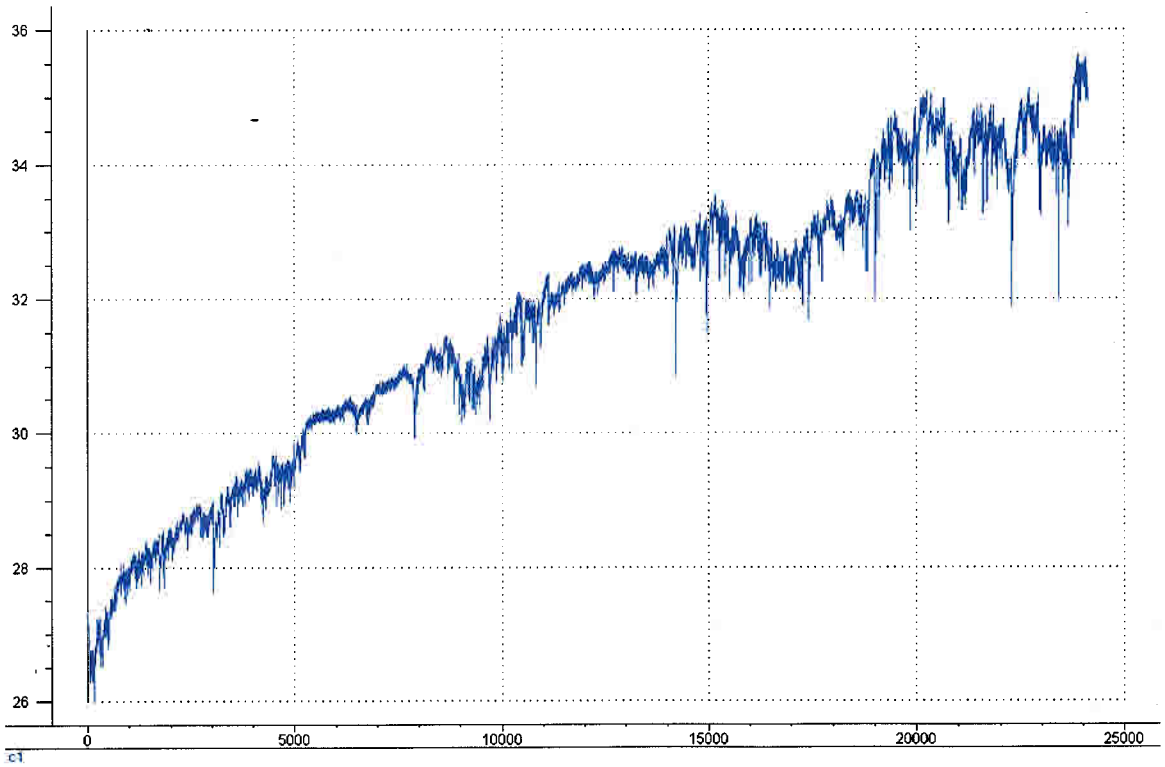
In the following figures, average values are illustrated for test persons sitting on three different cushions.

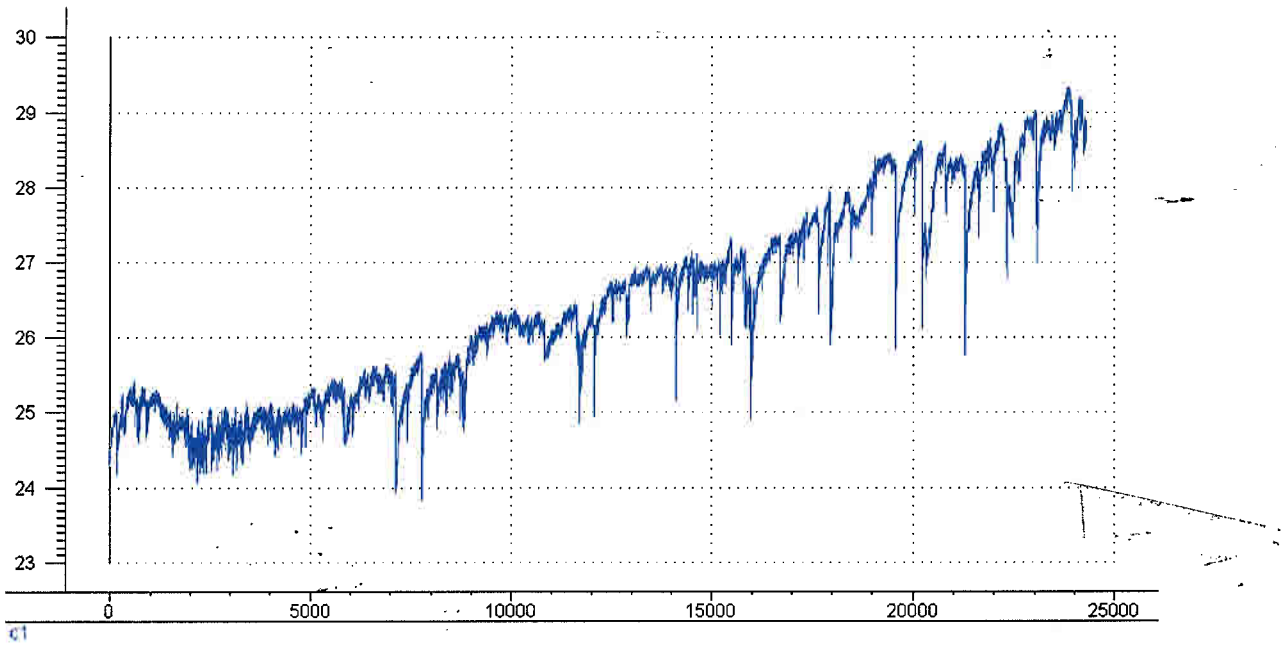
Figure 4: Test person on a regular cushion without pressure relieving properties



The first example is a regular cushion without special pressure dampening capabilities (12000 samples). As shown in Figure 4, there are less fluctuations in the measurements, probably due to the inadequate capabilities of the seat.

Figure 5a and 5b: Testpersons on cushions with pressure-relieving effect





The last two figures illustrate average mean values obtained from cushions seated by two different persons. The fluctuations are higher than with the first cushion. The pressure has probably levelled out on the surface of the cushion, making it more comfortable. Comparing the shape of the last two figures, there are some differences, especially during the first minutes of the recordings.

As another approach to studying the instrumental drift, Principal Component Analysis was performed on some data sets. The conclusion from these studies was that the instrumental drift should be corrected for directly based on its properties.

These initial experiments indicate that the instrumental drift is dependent on pressure; the higher the pressure, the higher the relative drift. More thorough studies need to be carried out in order to estimate the instrumental drift more accurately. It will then be possible to compensate for this effect in the study of seat cushions. With this kind of experiment, it is also possible to estimate the accuracy of the measurements (mean values, standard deviations).

3 RESULTS

3.1 Pressure mapping

In the following section, frequency distributions for the entire measurement period will be presented for all cushions. In addition, images of the pressure distribution of each testperson on each cushion after 90 minutes will illustrate eventual differences among subjects.

3.1.1 Cushion : Caresit MFE 600

Figure 6a: Fregency distribution: All recorded values

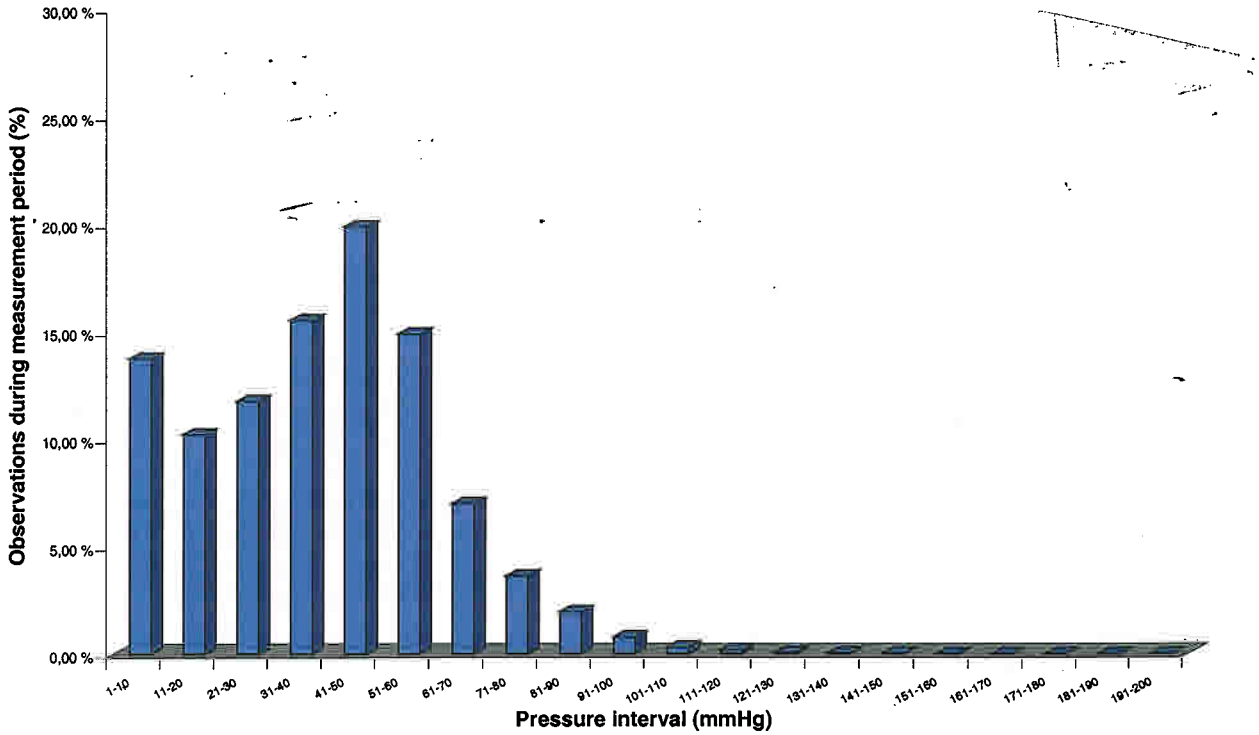
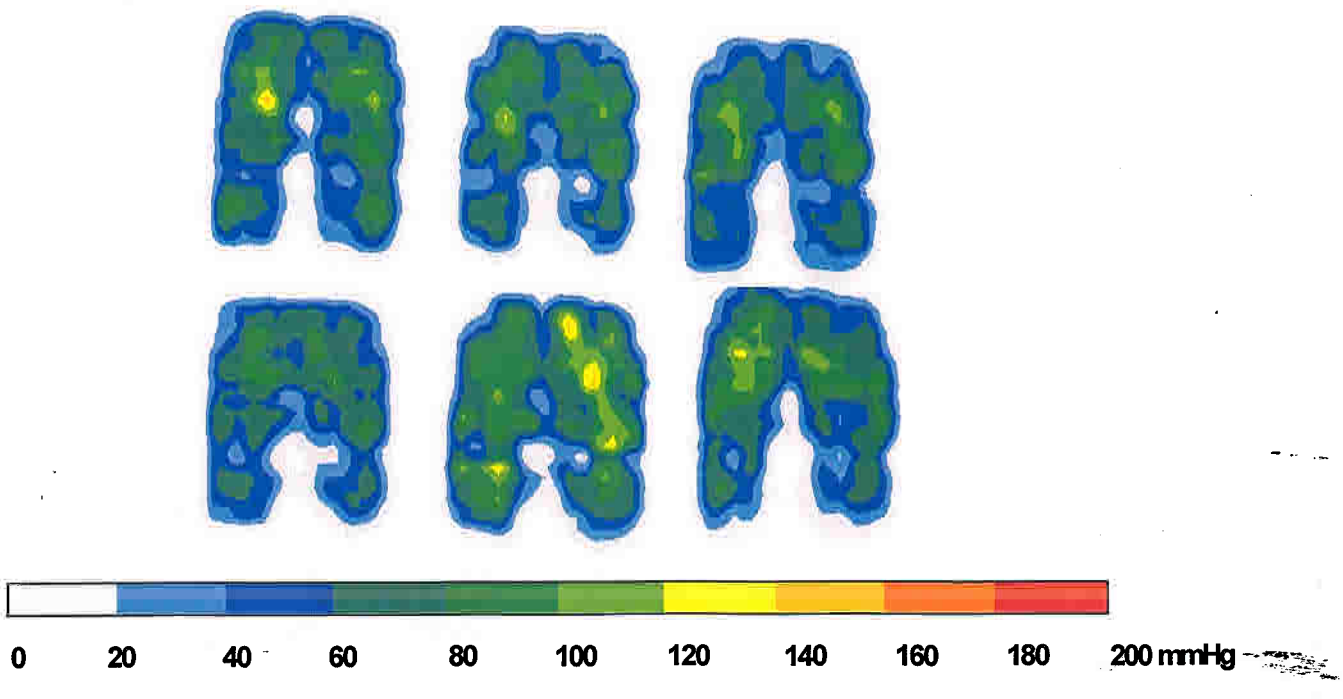


Figure 6b: Comparison of pressure distribution: All six subjects after 90 minutes



3.1.2 Cushion: Caresit MFE 601 Split

Figure 7a: Freqency distribution: All recorded values

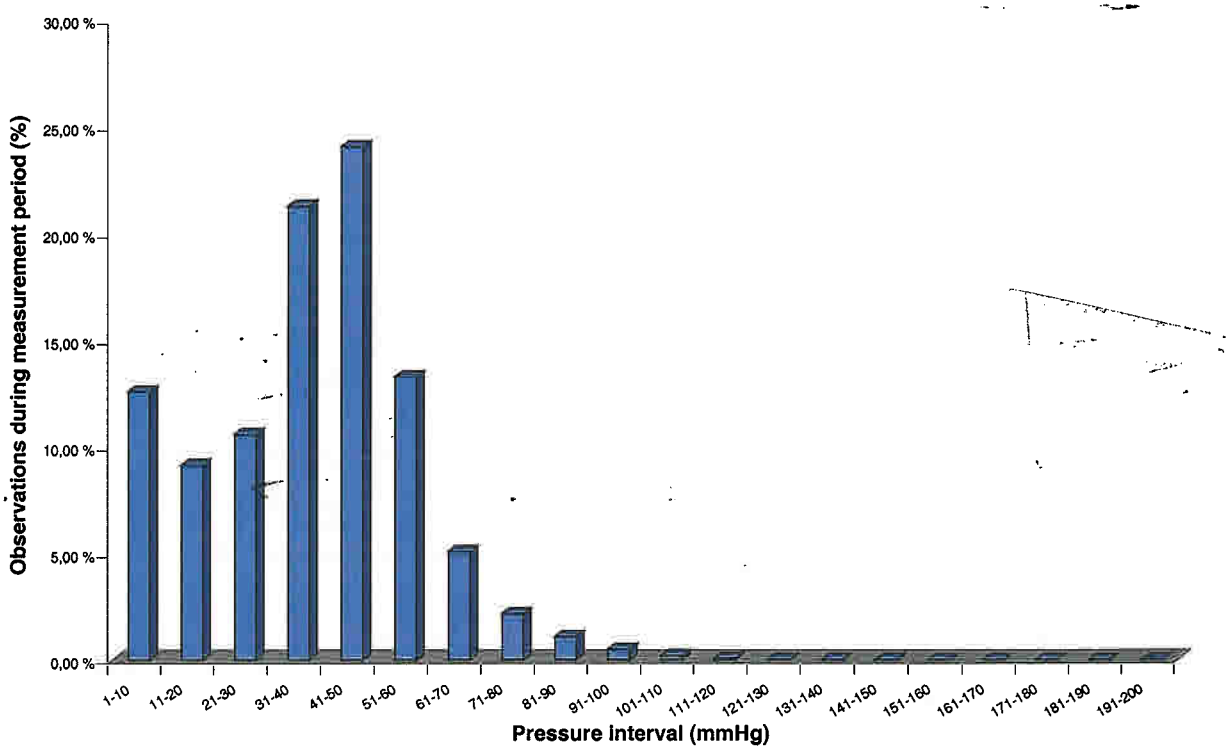
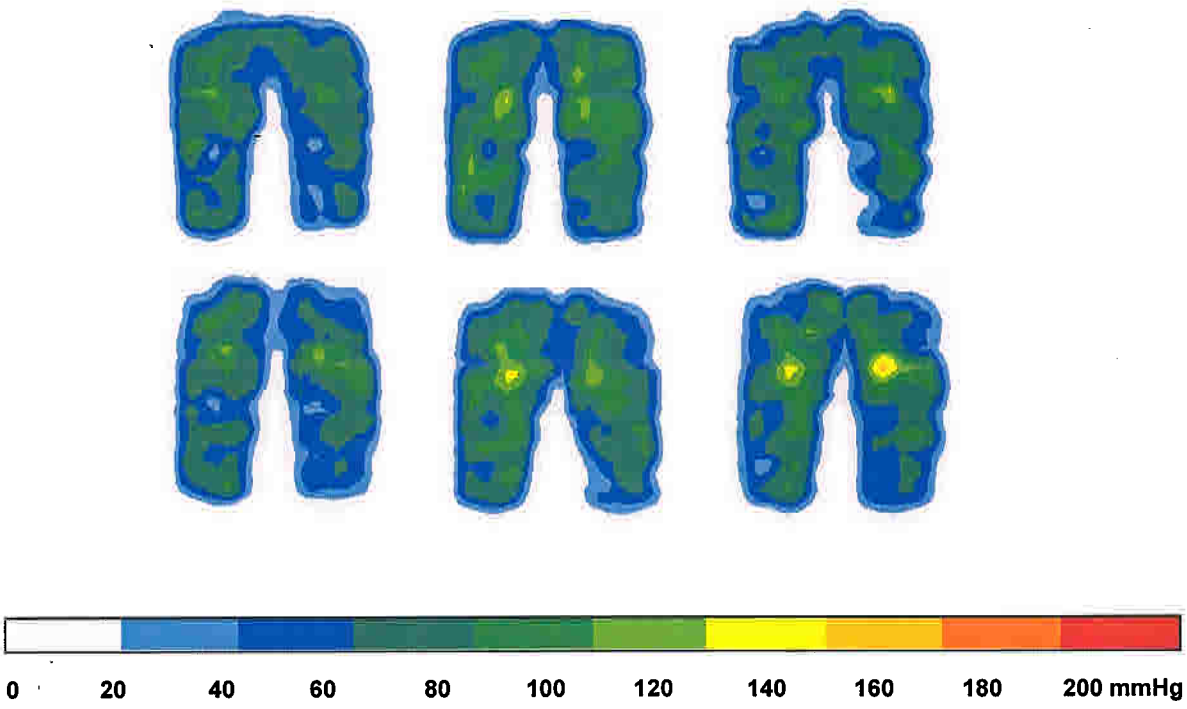


Figure 7b: Comparison of pressure distribution: All six subjects after 90 minutes



3.1.3 *Cushion: Infinity Airflow*

Figure 8a: Freqency distribution: All recorded values

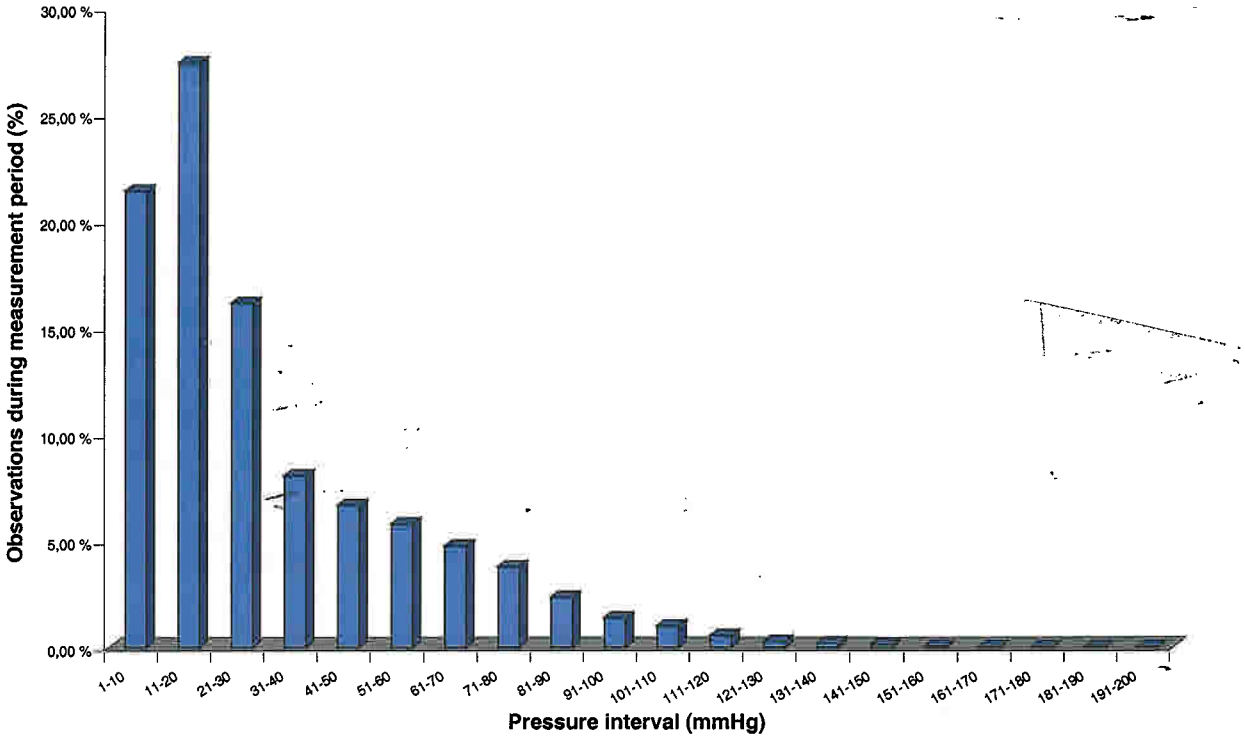
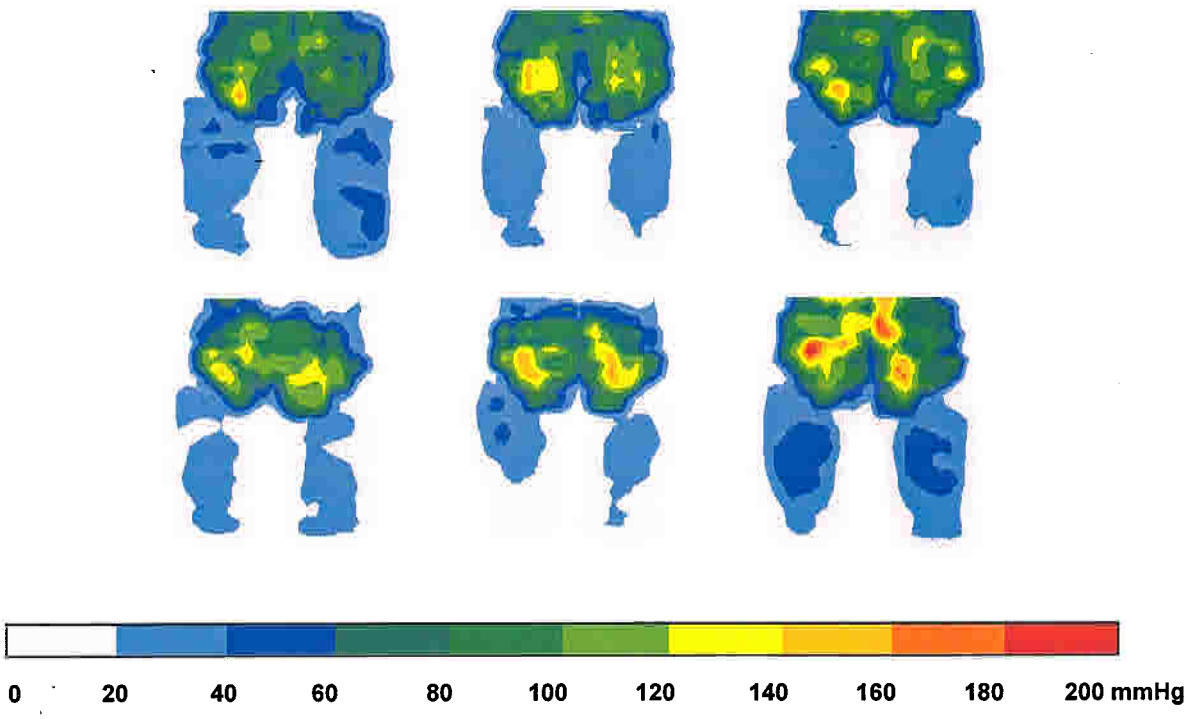


Figure 8b: Comparison of pressure distribution: All six subjects after 90 minutes



3.1.4 Cushion: Jay2 Deep Contour

Figure 9a: Frequency distribution: All recorded values

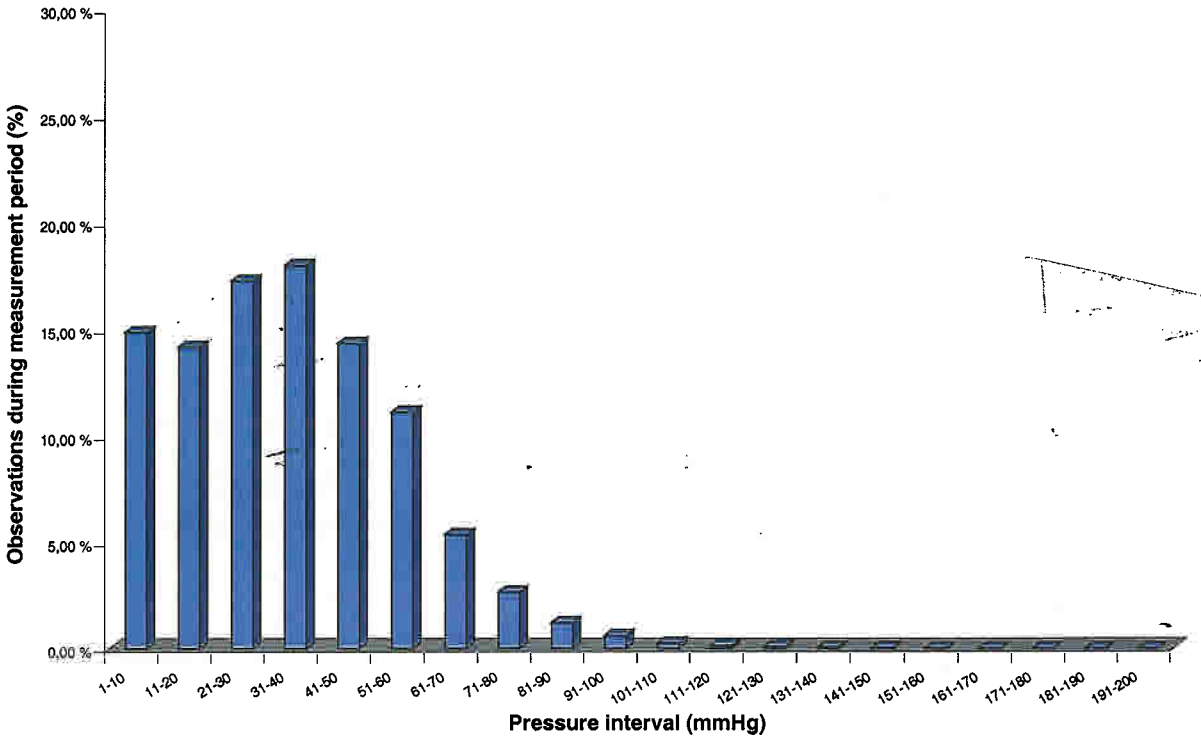
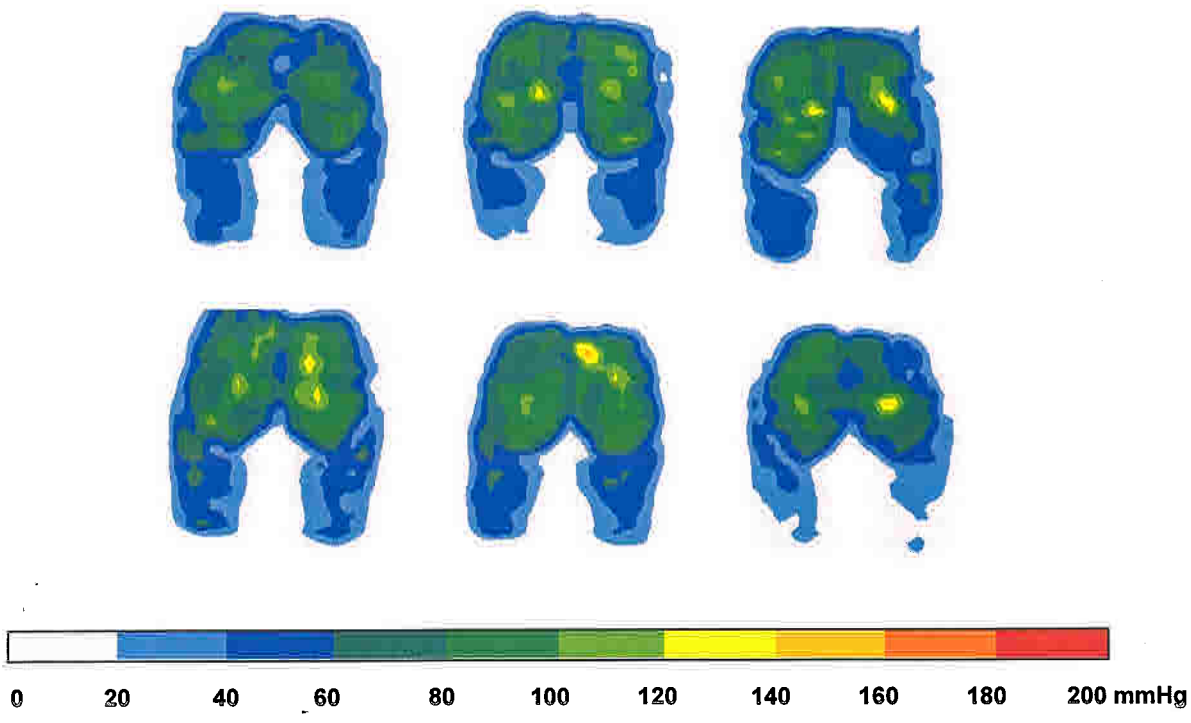


Figure 9b: Comparison of pressure distribution: All six subjects after 90 minutes



3.1.5 Cushion : Jay Triad

Figure 10a: Frequency distribution: All recorded values

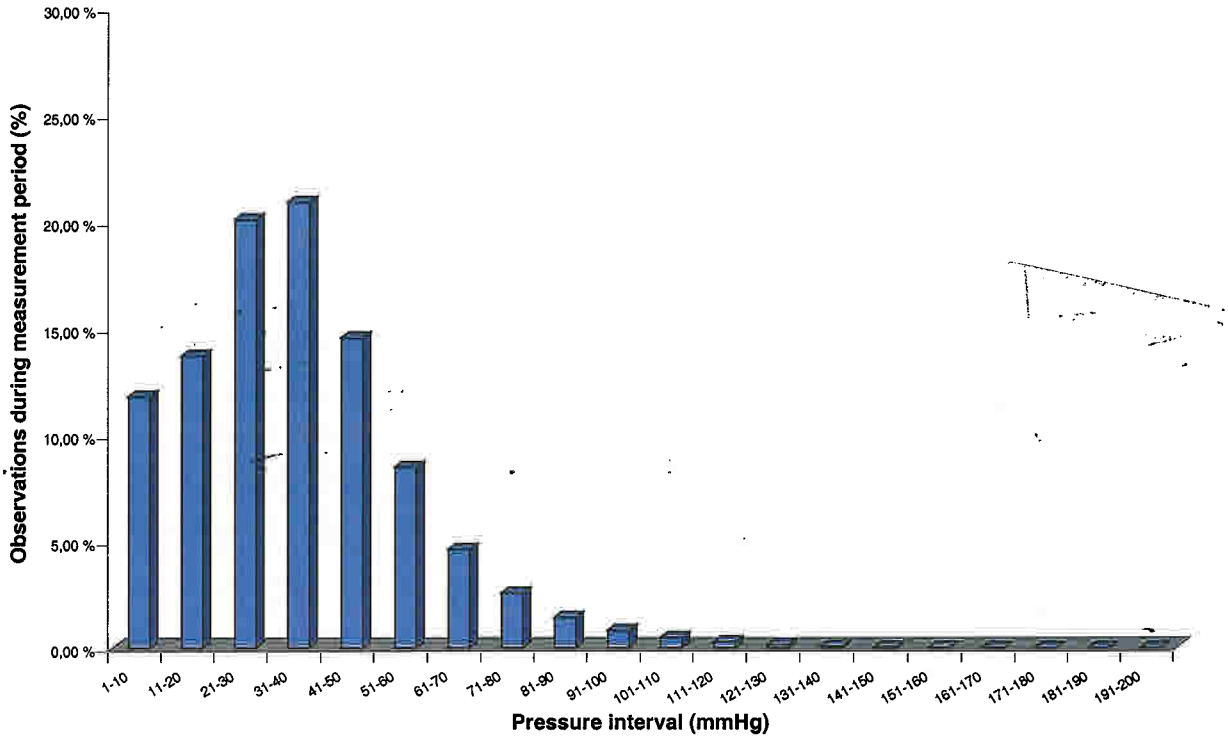
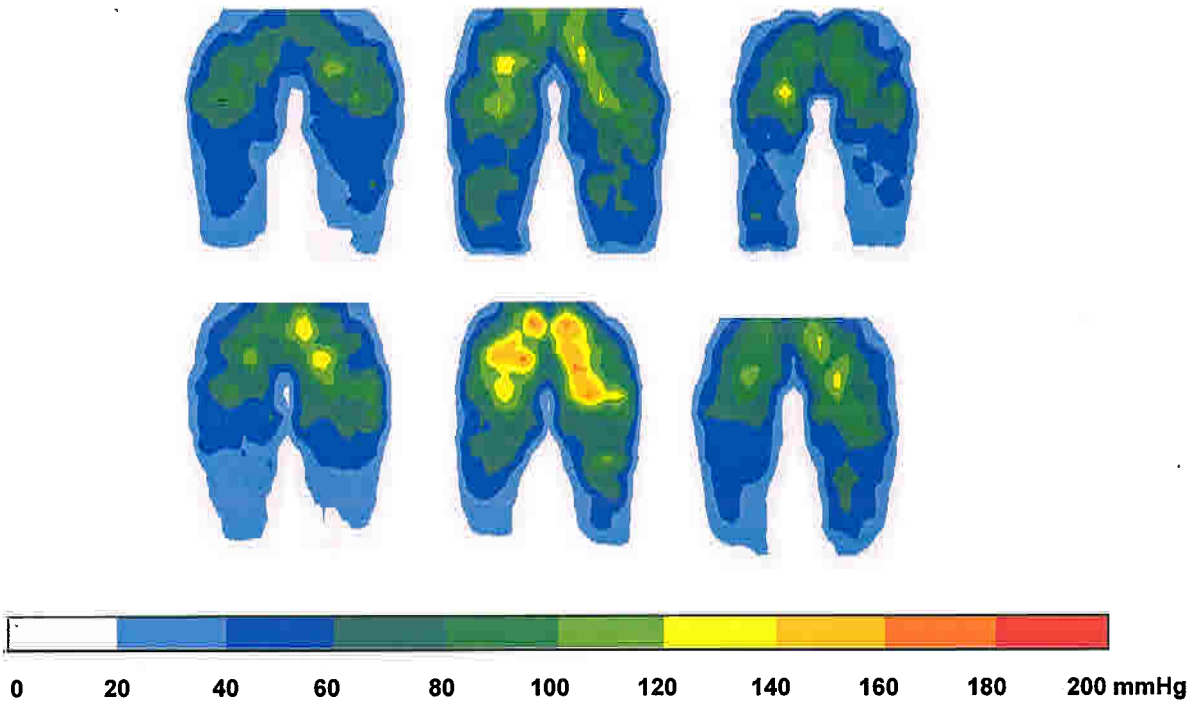


Figure 10b: Comparison of pressure distribution: All six subjects after 90 minutes



3.1.6 Cushion: Kineris

Figure 11a: Frequency distribution: All recorded values

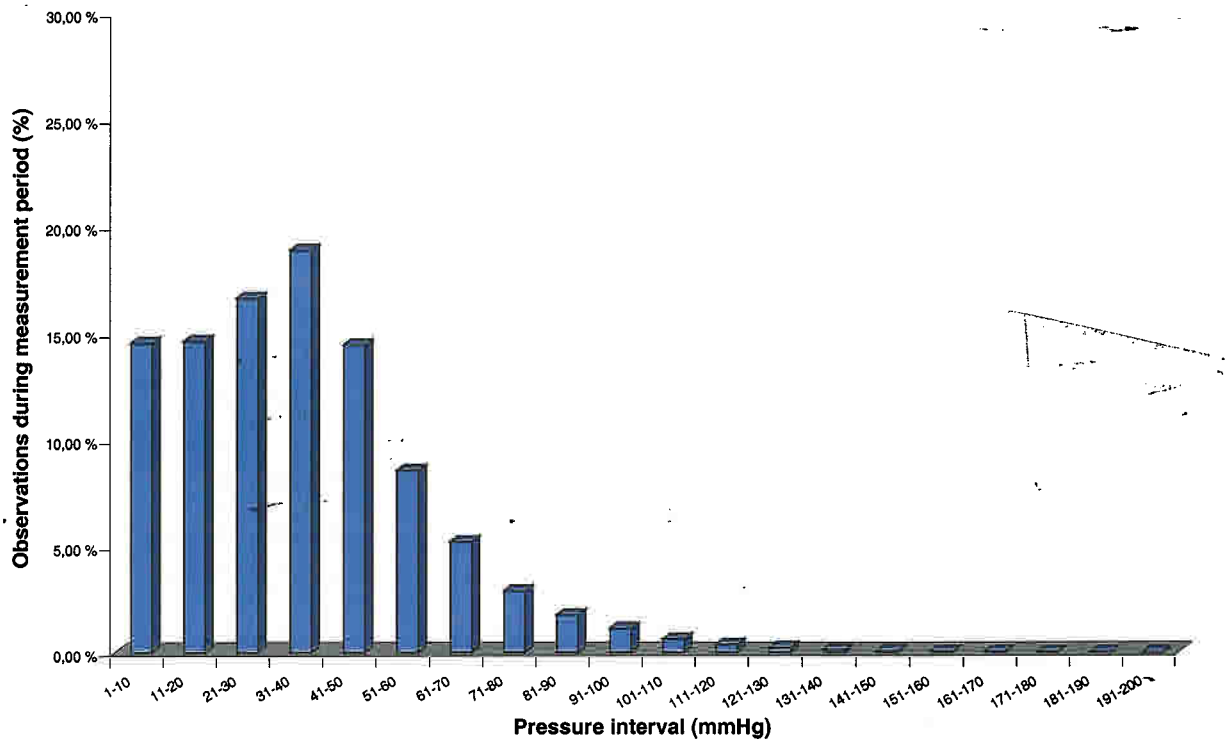
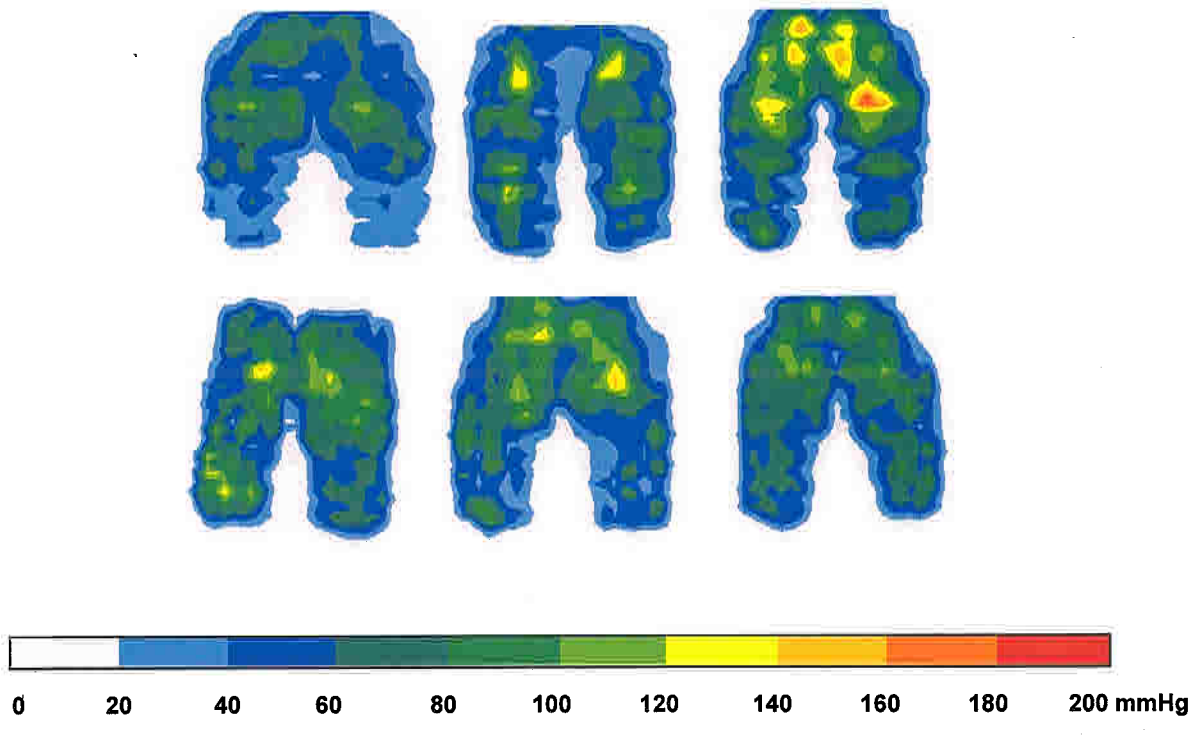


Figure 11b: Comparison of pressure distribution: All six subjects after 90 minutes



3.1.7 Cushion: ROHO Quadtro Select

Figure 12a: Frequency distribution: All recorded values

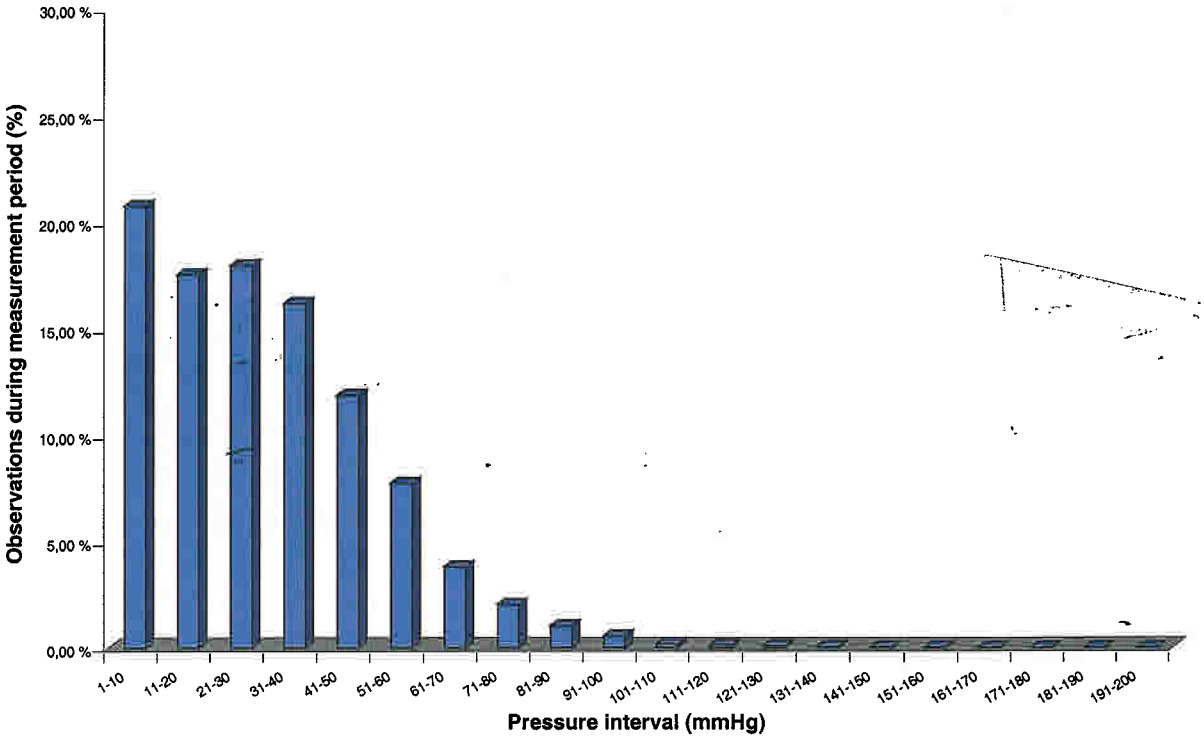
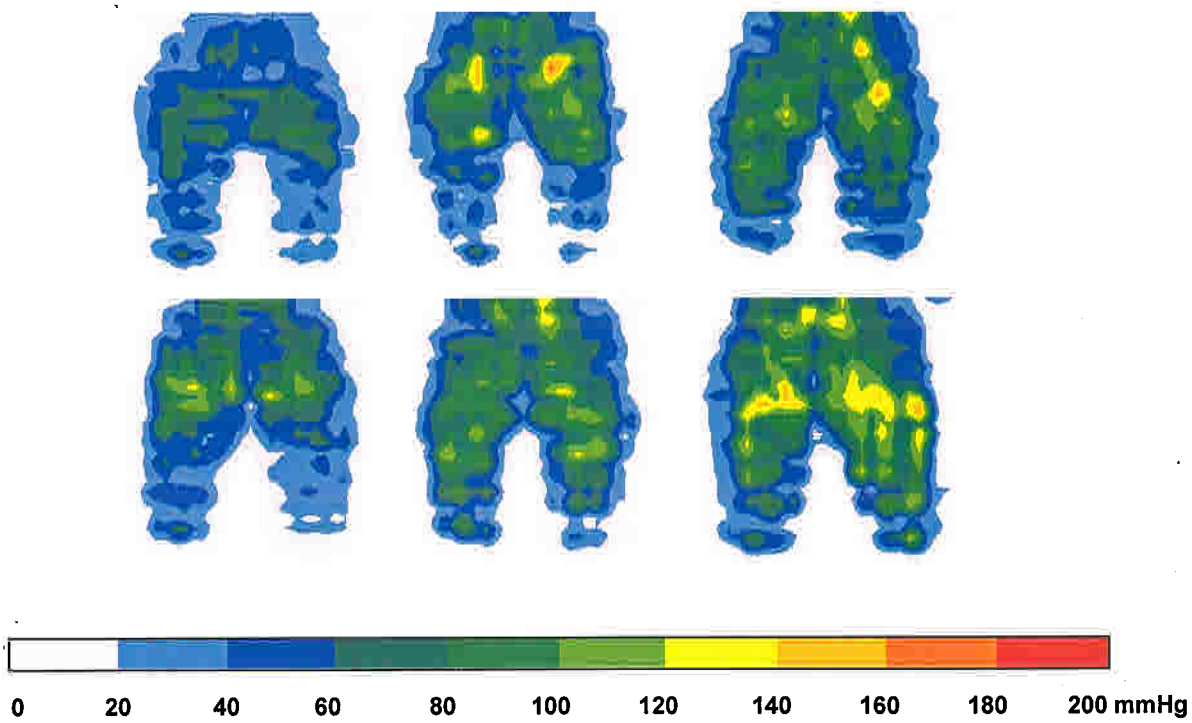


Figure 12b: Comparison of pressure distribution: All six subjects after 90 minutes



3.1.8 Cushion : ROHO Spirit Nexus

Figure 13a: Frequency distribution: All recorded values

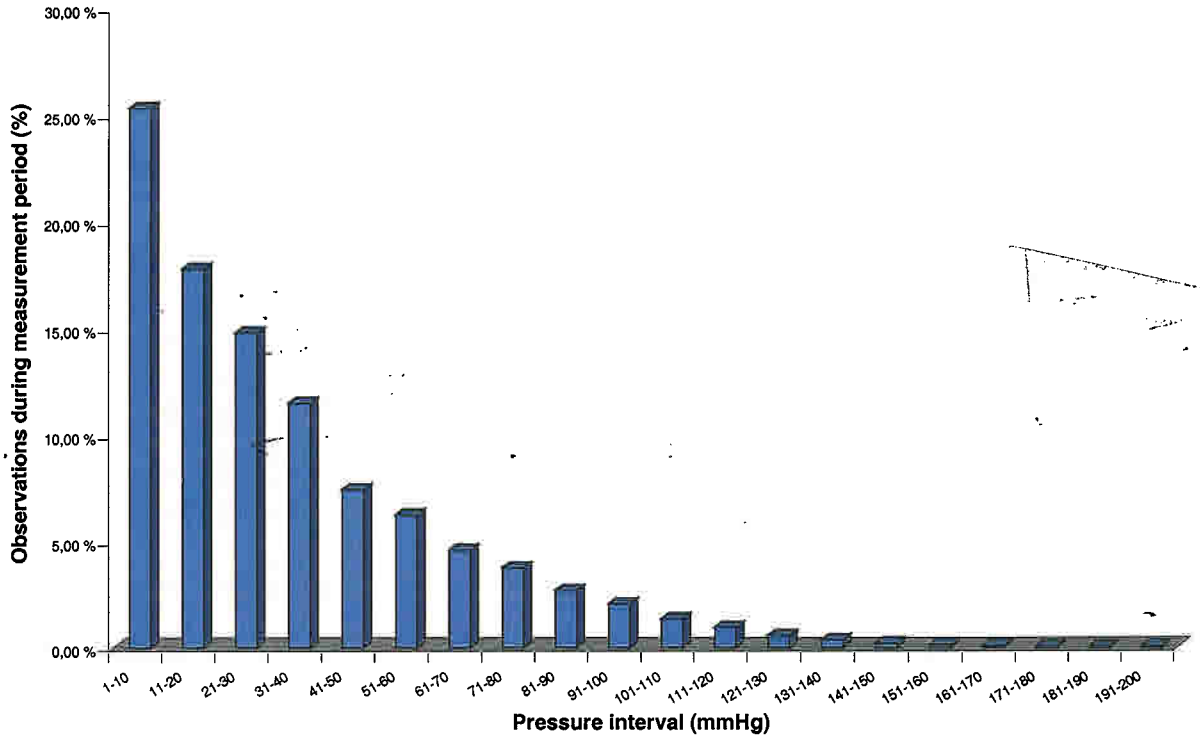
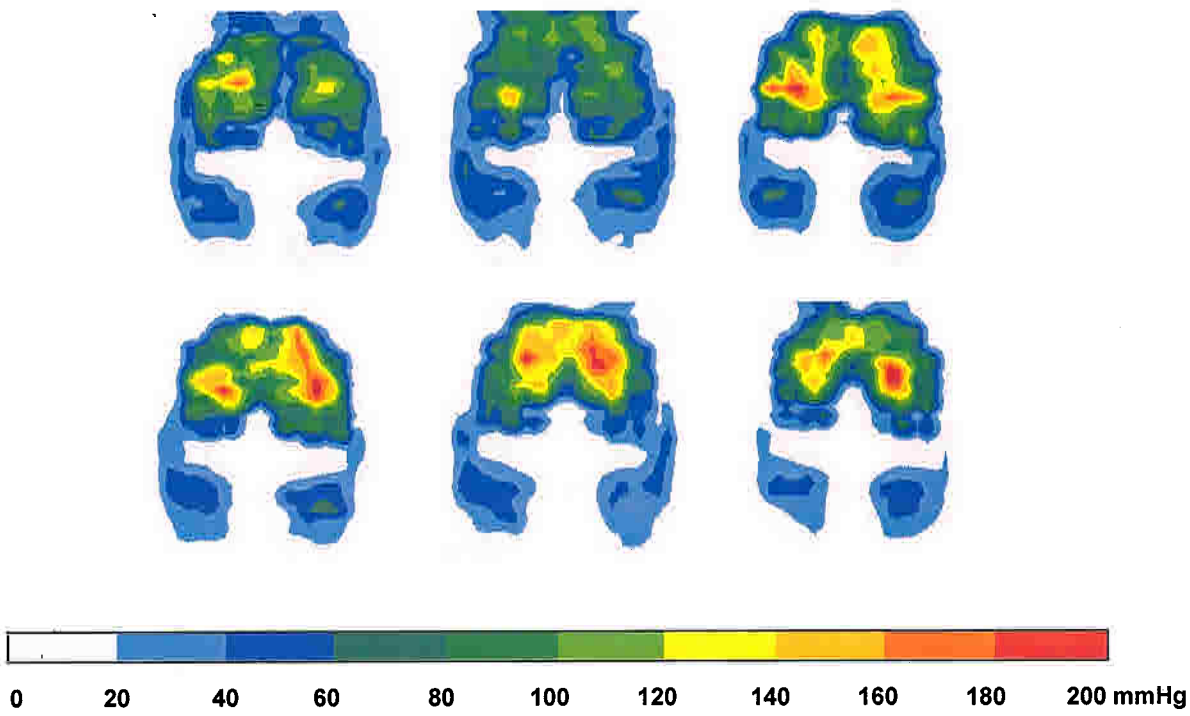


Figure 13b: Comparison of pressure distribution: All six subjects after 90 minutes



3.1.9 Cushion : SmartSit 1

Figure 14a: Frequency distribution: All recorded values

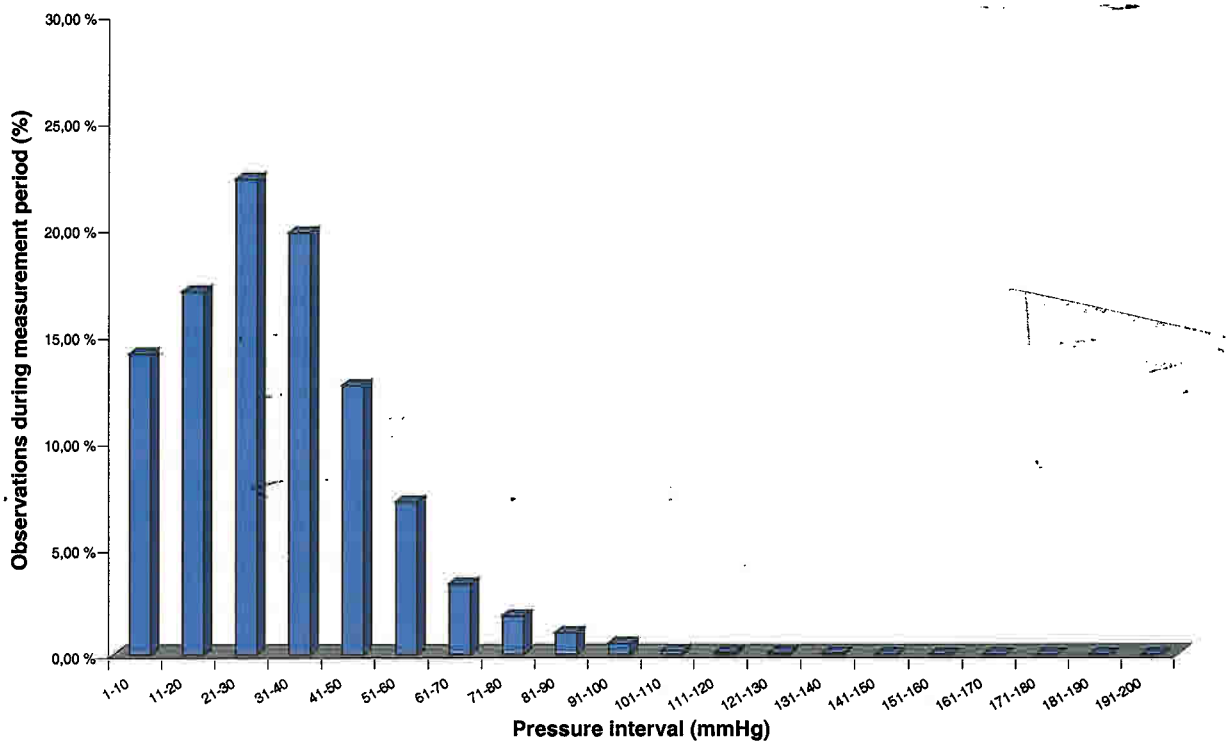
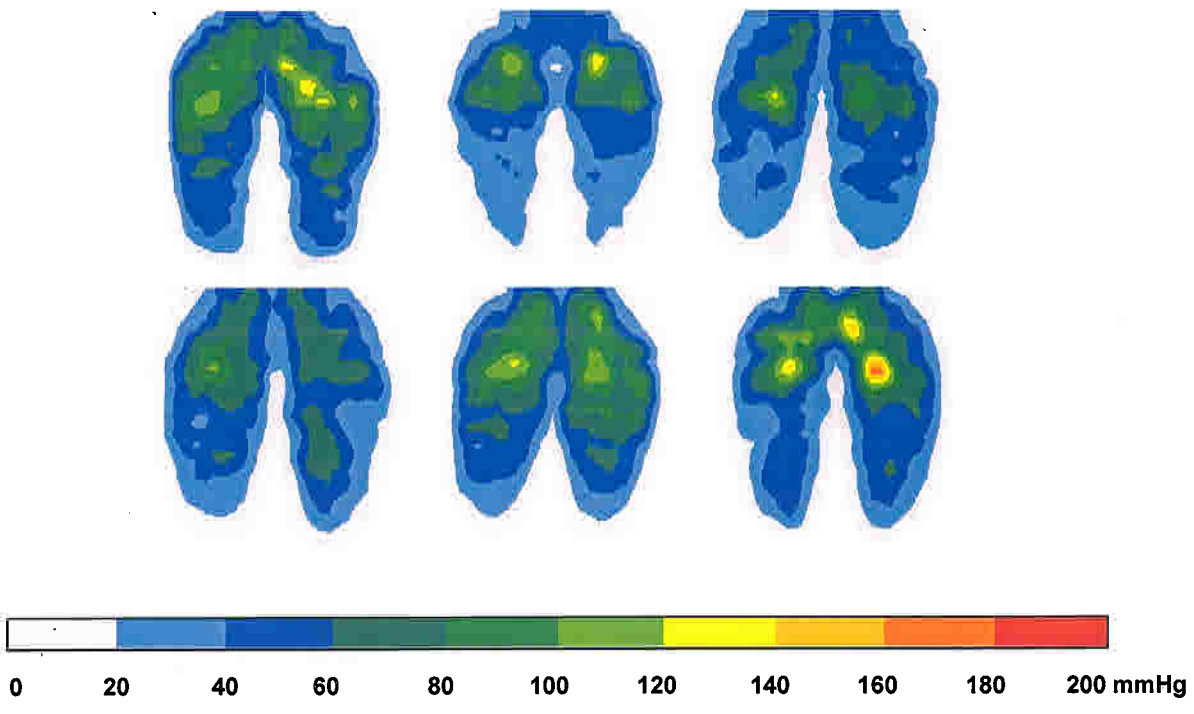


Figure 14b: Comparison of pressure distribution: All six subjects after 90 minutes



3.1.10 Cushion : SmartSit 2

Figure 15a: Frequency distribution: All recorded values

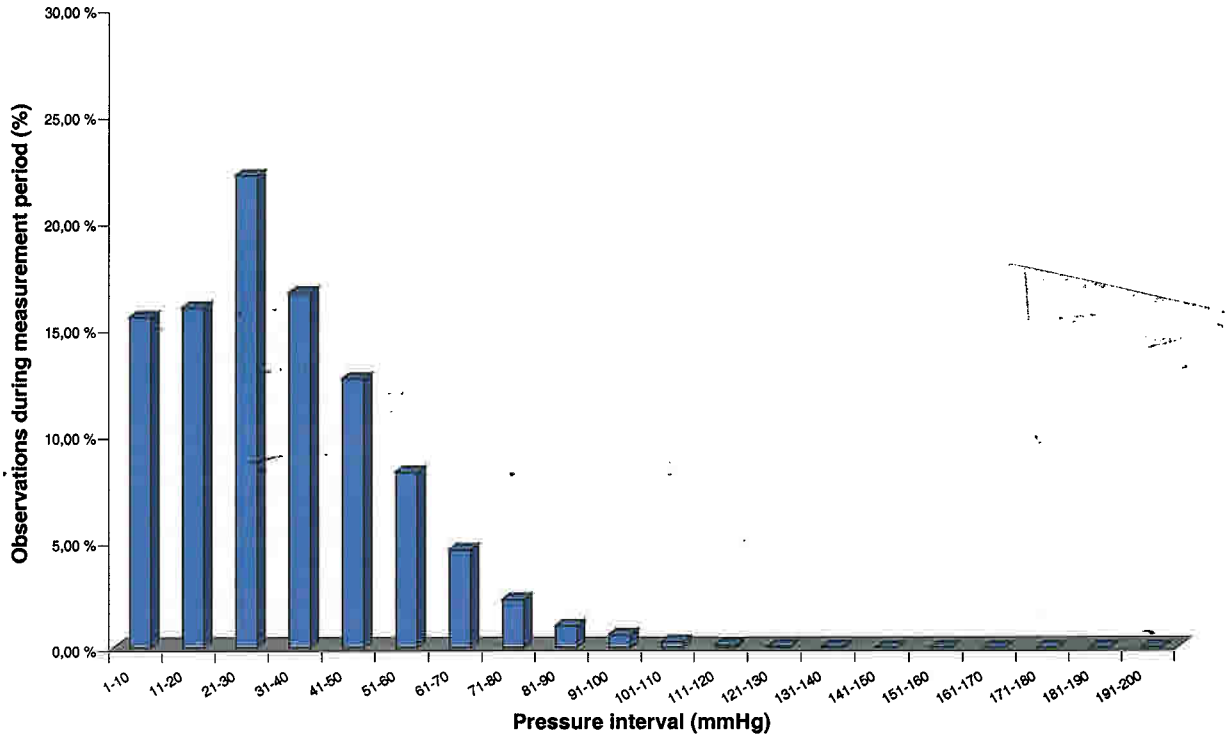
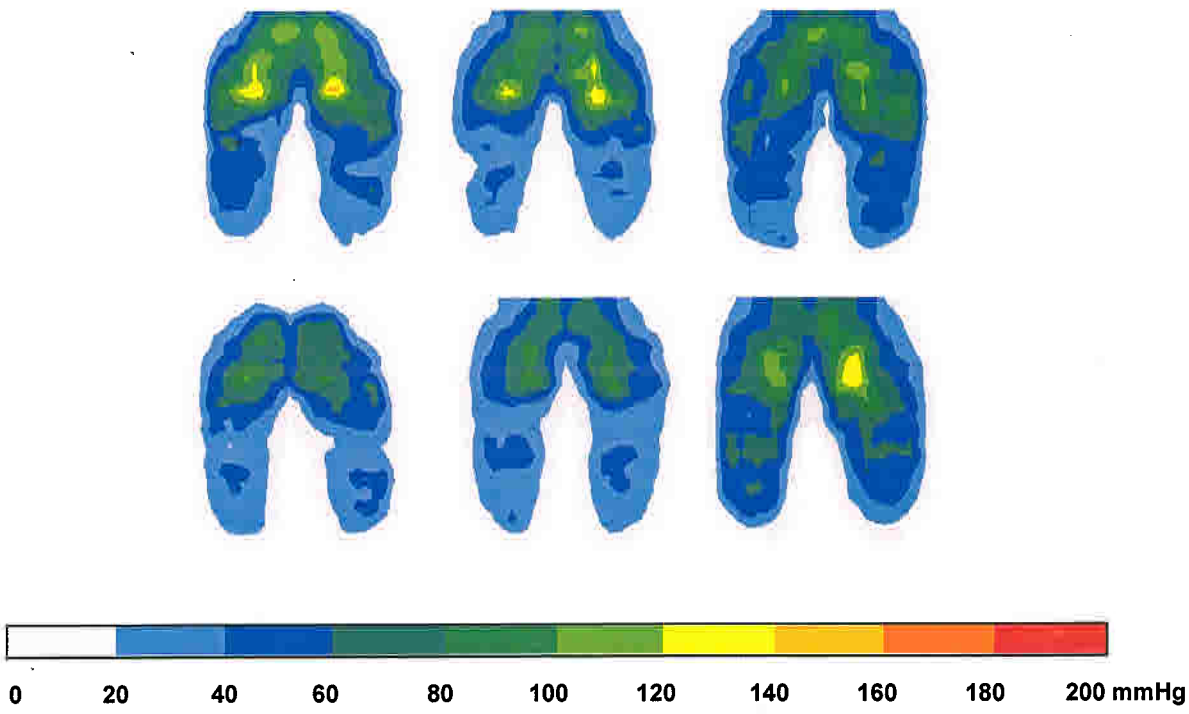


Figure 15b: Comparison of pressure distribution: All six subjects after 90 minutes



3.1.11 Cushion: Tempur

Figure 16a: Frequency distribution: All recorded values

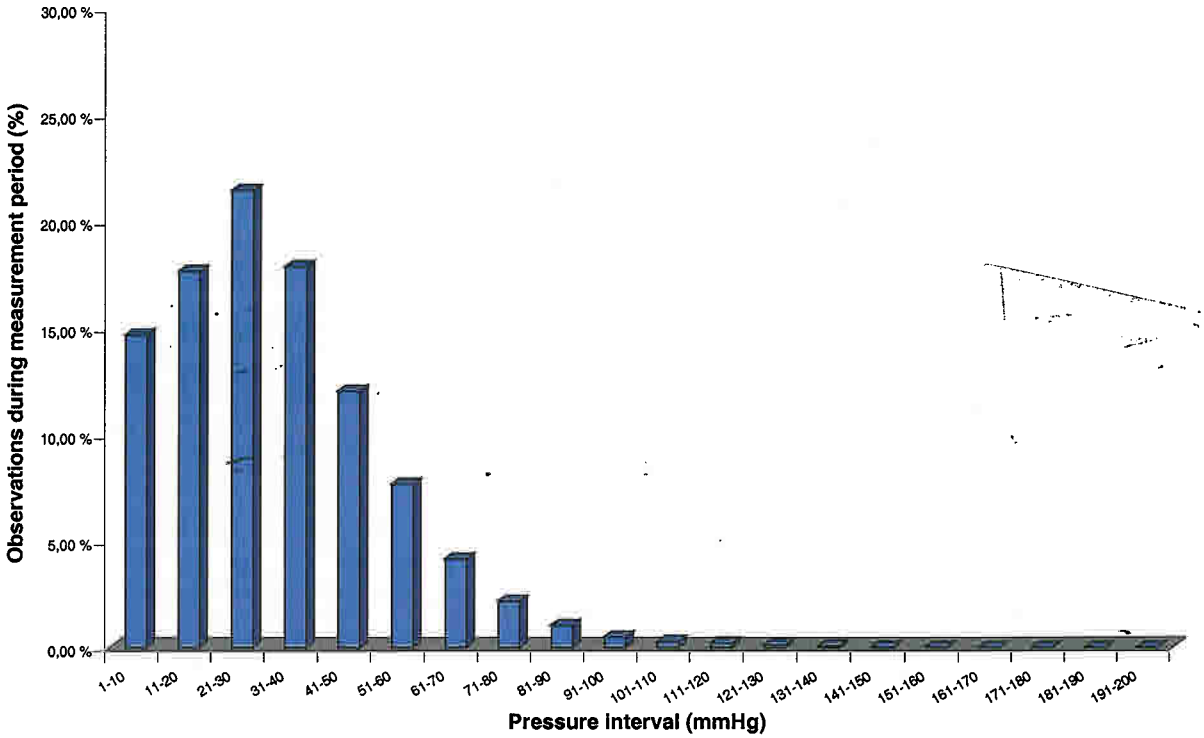
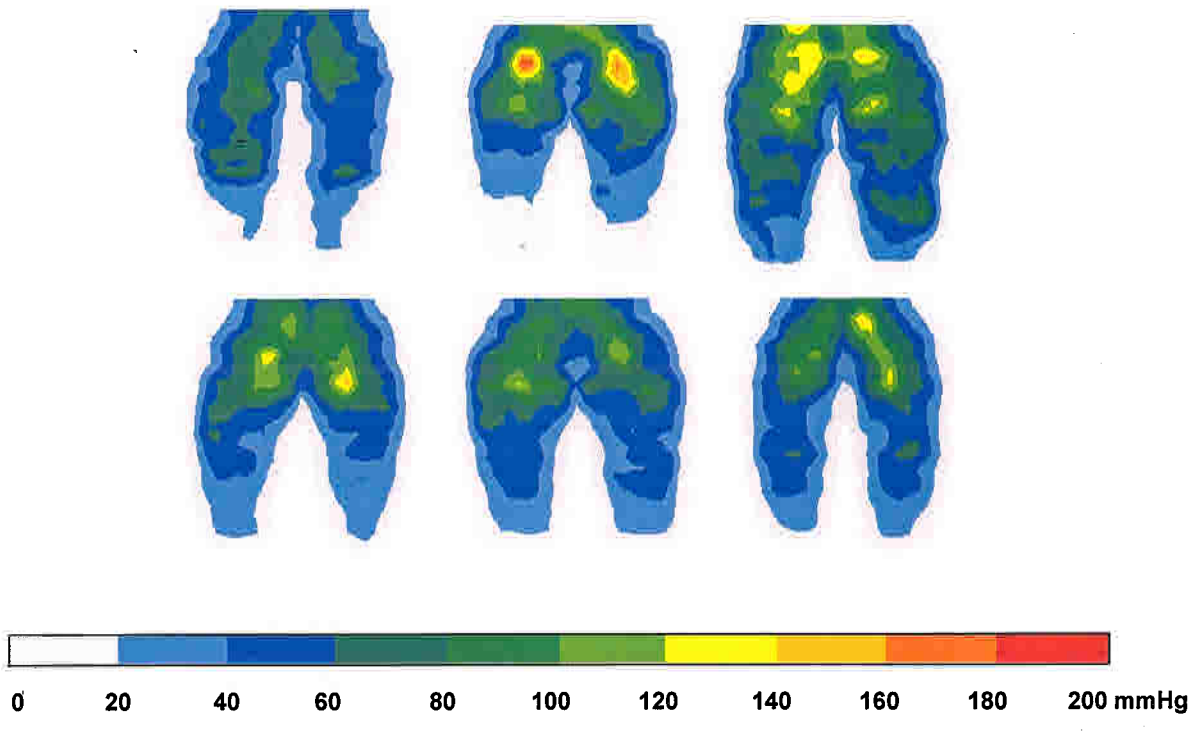


Figure 16b: Comparison of pressure distribution: All six subjects after 90 minutes



3.1.12 Cushion: Vicair Adjuster

Figure 17a: Frequency distribution: All recorded values

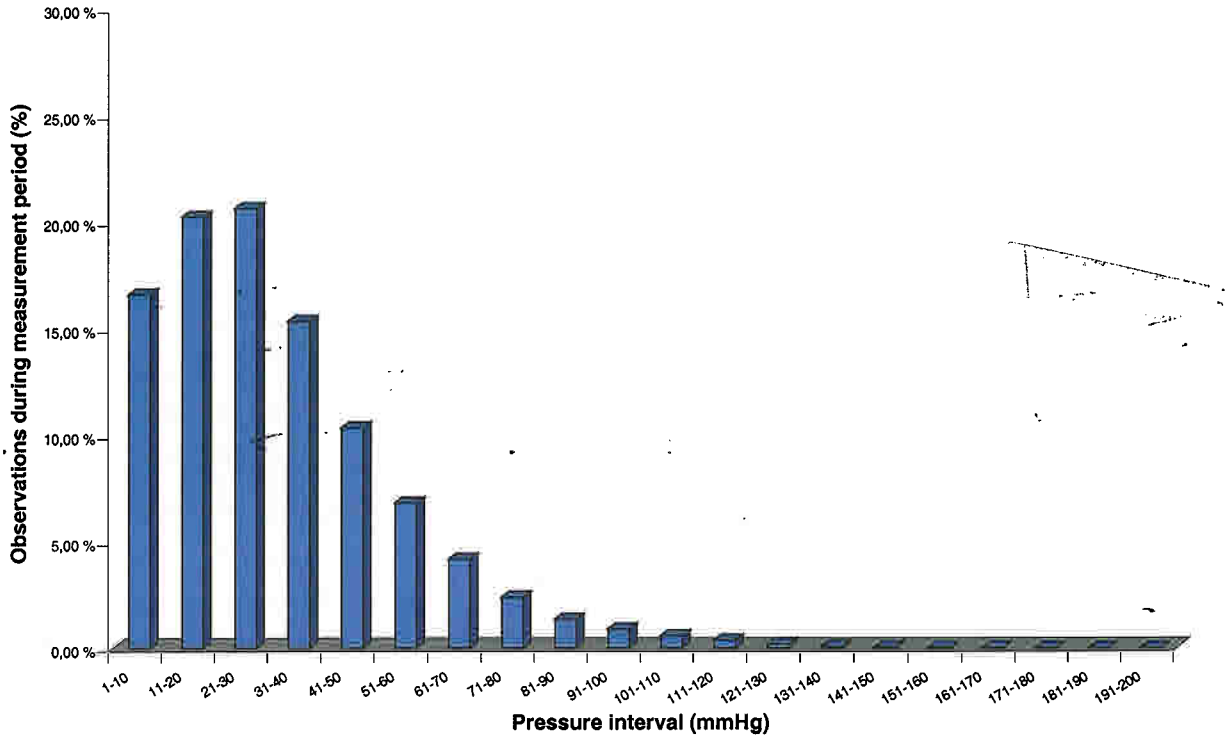
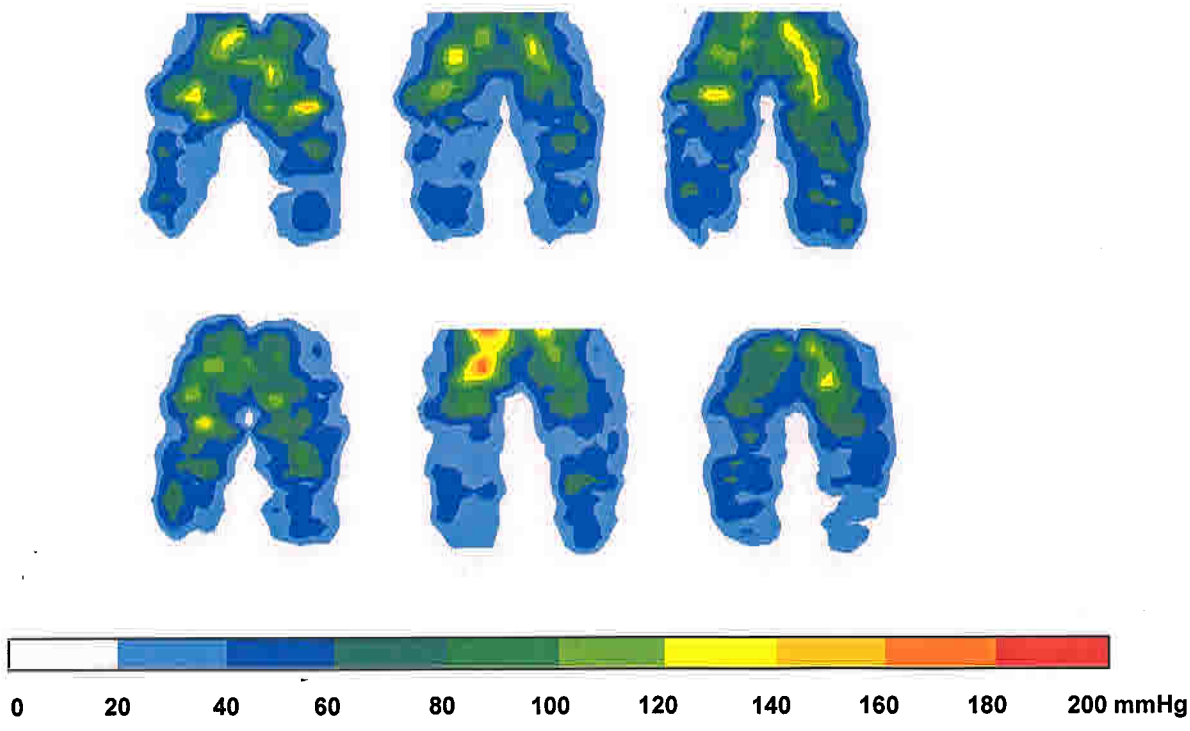


Figure 17b: Comparison of pressure distribution: All six subjects after 90 minutes



3.1.13 Cushion: Vicair Positioner Plus 10

Figure 18a: Frequency distribution: All recorded values

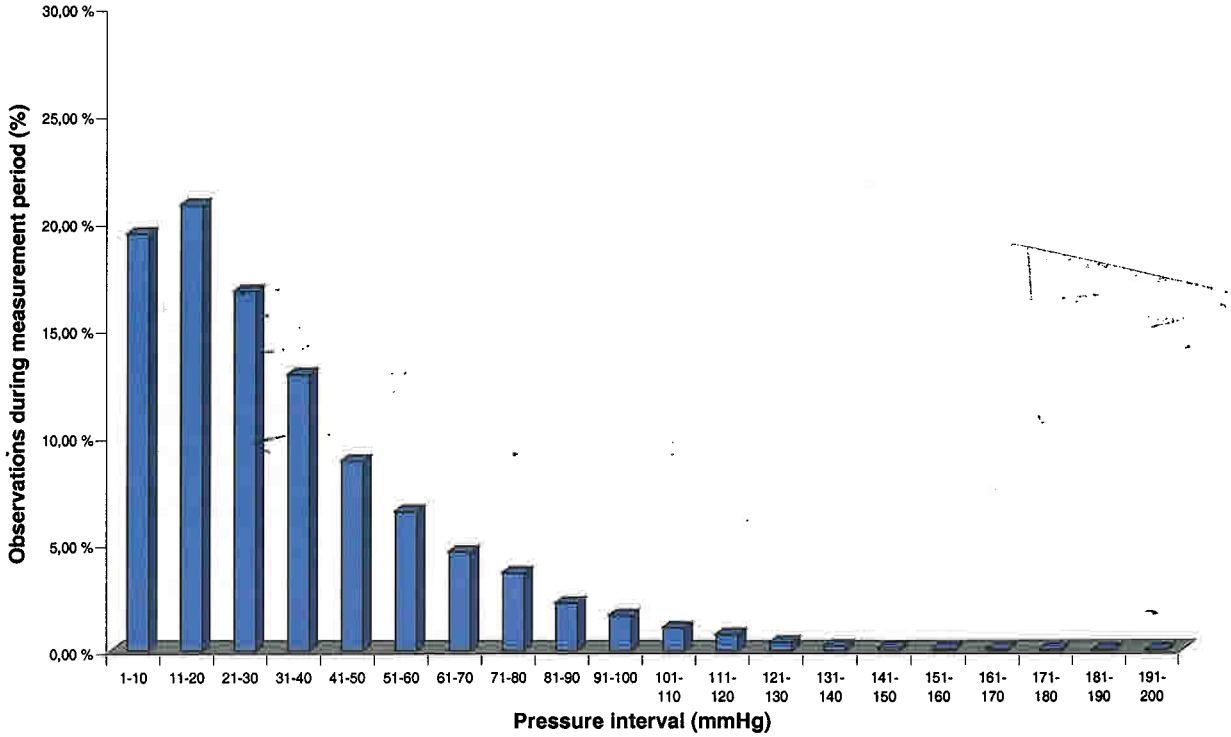
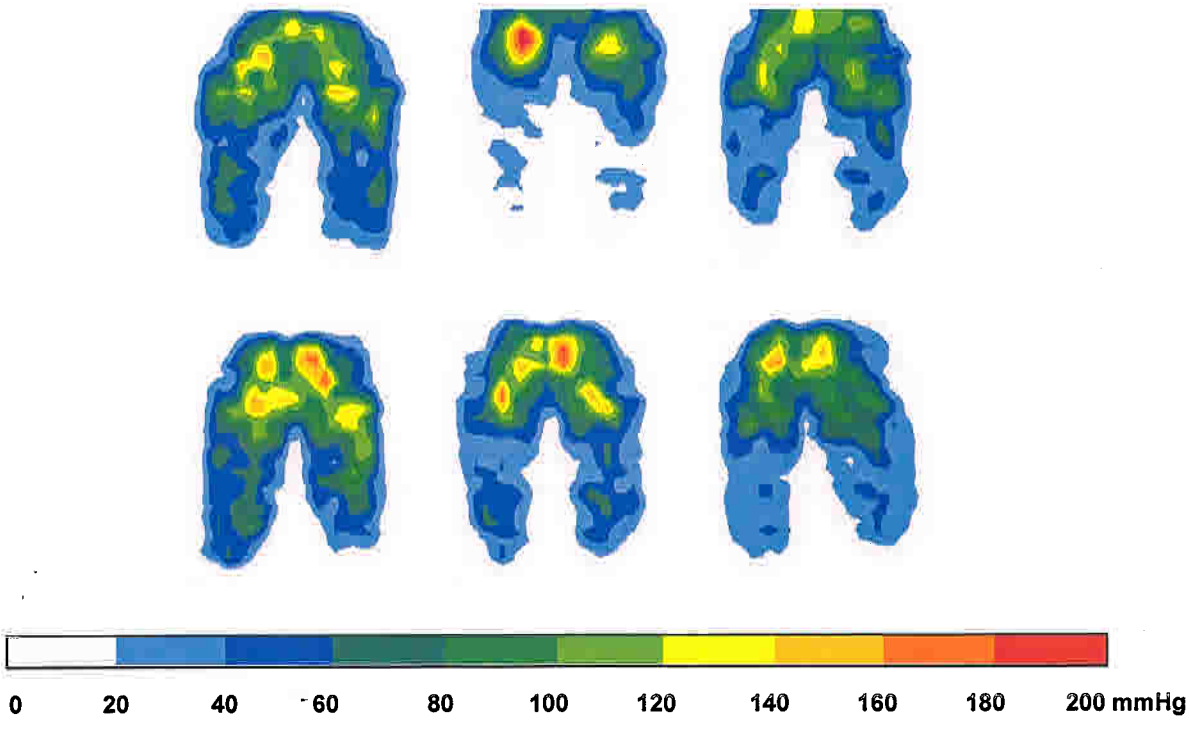


Figure 18b: Comparison of pressure distribution: All six subjects after 90 minutes



3.1.14 Cushion : VitalBase Active

Figure 19a: Frequency distribution: All recorded values

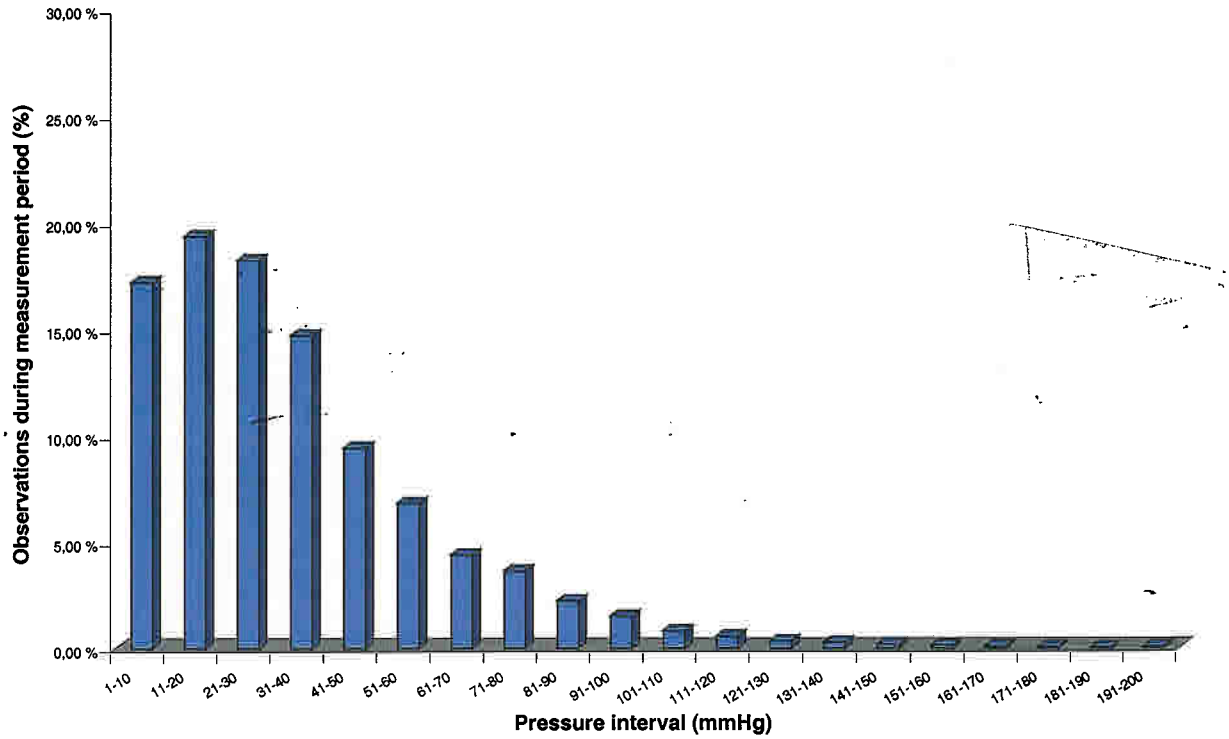
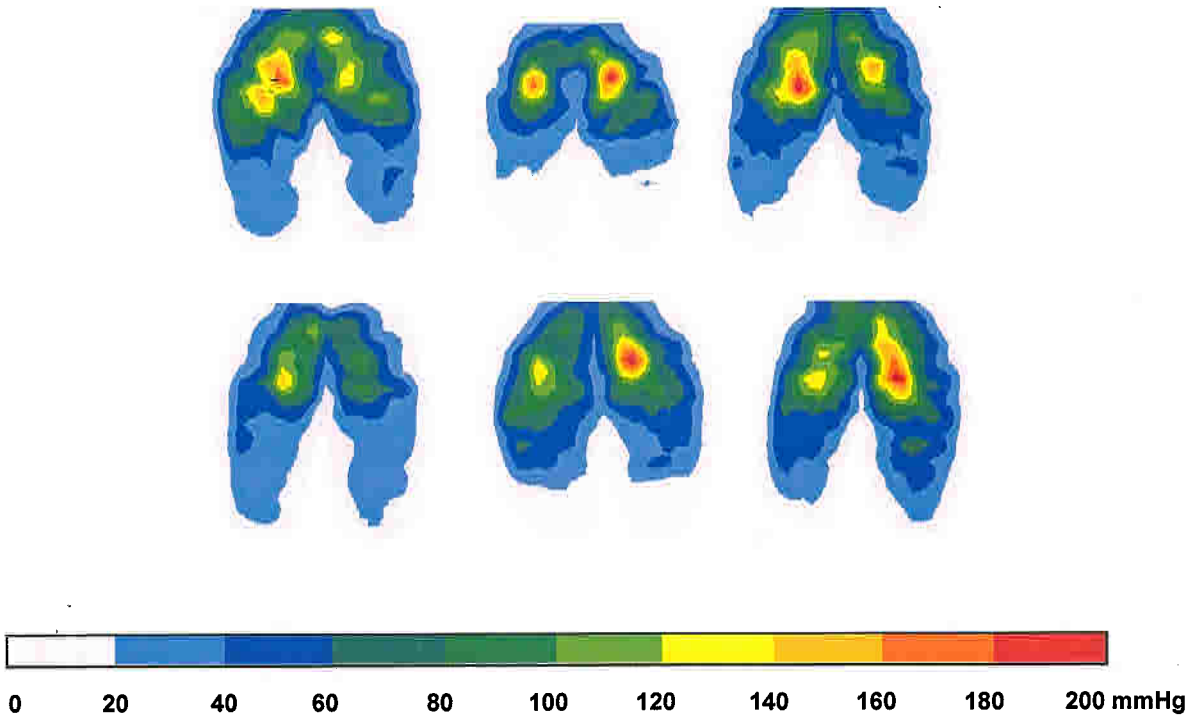


Figure 19b: Comparison of pressure distribution: All six subjects after 90 minutes



3.1.15 *Cushion: VitalBase Royal*

Figure 20a: Frequency distribution: All recorded values

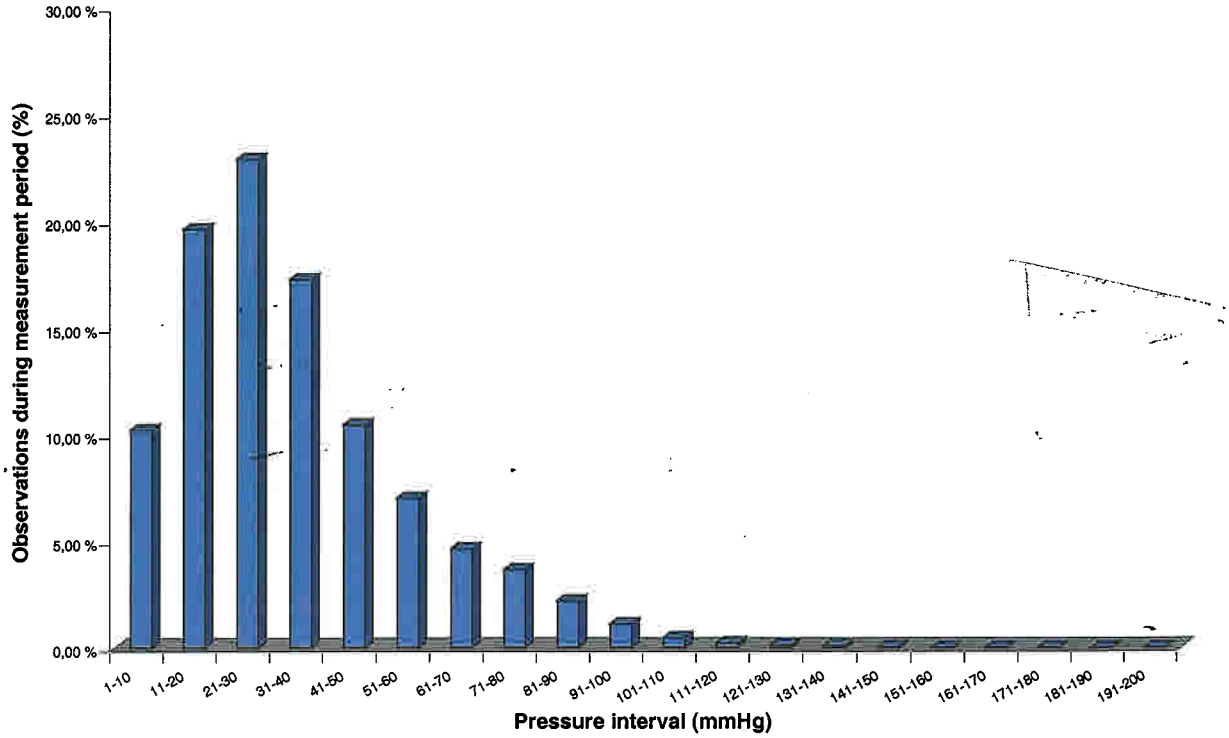
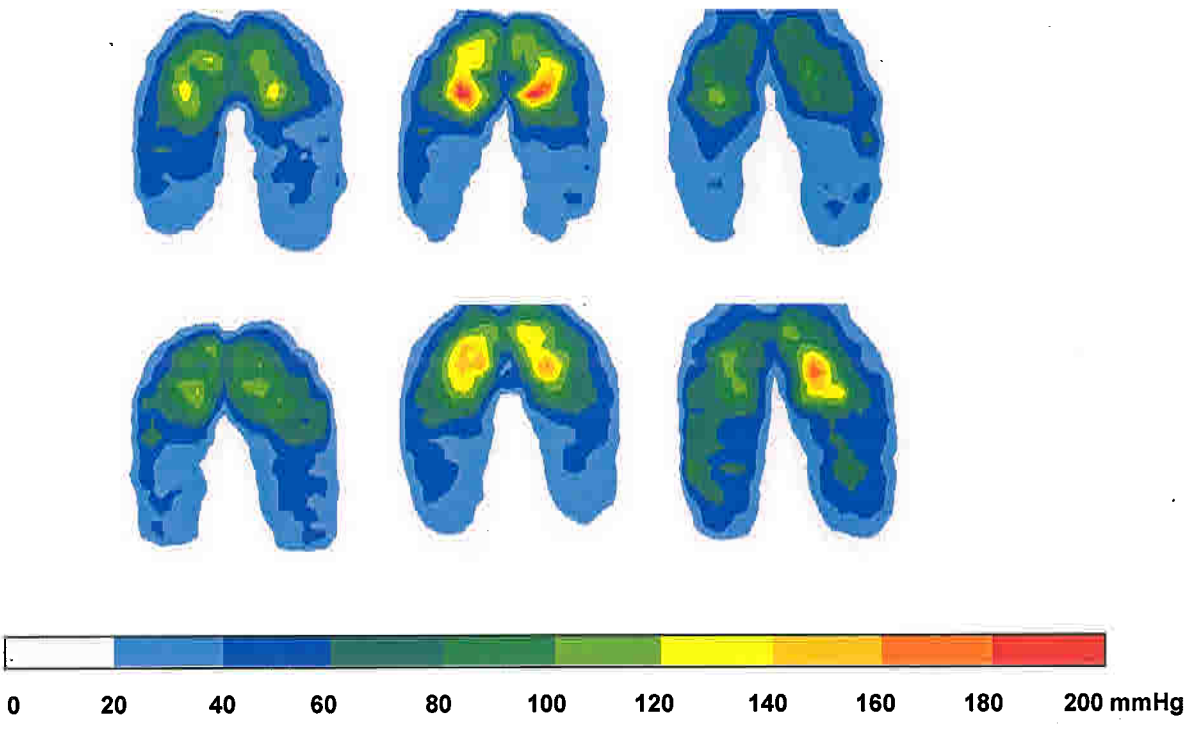


Figure 20b: Comparison of pressure distribution: All six subjects after 90 minutes



As shown in figures 6-20a, frequency distributions are not equal for the different cushions. To test whether these apparent differences within each pressure interval may be coincidental, a distribution free ANOVA-type test was performed. The test captures the variance within the groups. The test calculates the variation both inter- and intragroup, and concludes that although there is variation within groups, the by far predominant effect is the difference between groups. The (40-50 mmHg) interval was chosen for testing. The test showed that the probability that the differences between cushions in the chosen pressure interval are caused by chance is rejected at 0,002%. There appears to be no reason to suspect the observed differences in the other pressure intervals to differ from the interval tested. In other words: Dependable differences are manifested on the pressure distribution among the measured cushions.

Figures 6-20b reveal, in addition, obvious differences on pressure distribution patterns after 90 minutes between persons sitting on the same cushion. This underlines the fact that even if a cushion seems well-suited for one person, it may not be the best choice for another person. The question whether a cushion is appropriate or not is, indeed, highly individual. Equally interesting, and further enhancing the importance of individual adjustment for each user, we found that pressure distribution patterns also vary to a considerable extent for each subject when seated on six different cushions. Figures 21 and 22 below illustrate these findings.

Figure 21: Example 1, comparison of pressure distribution: One subject on six different cushions after 90 minutes

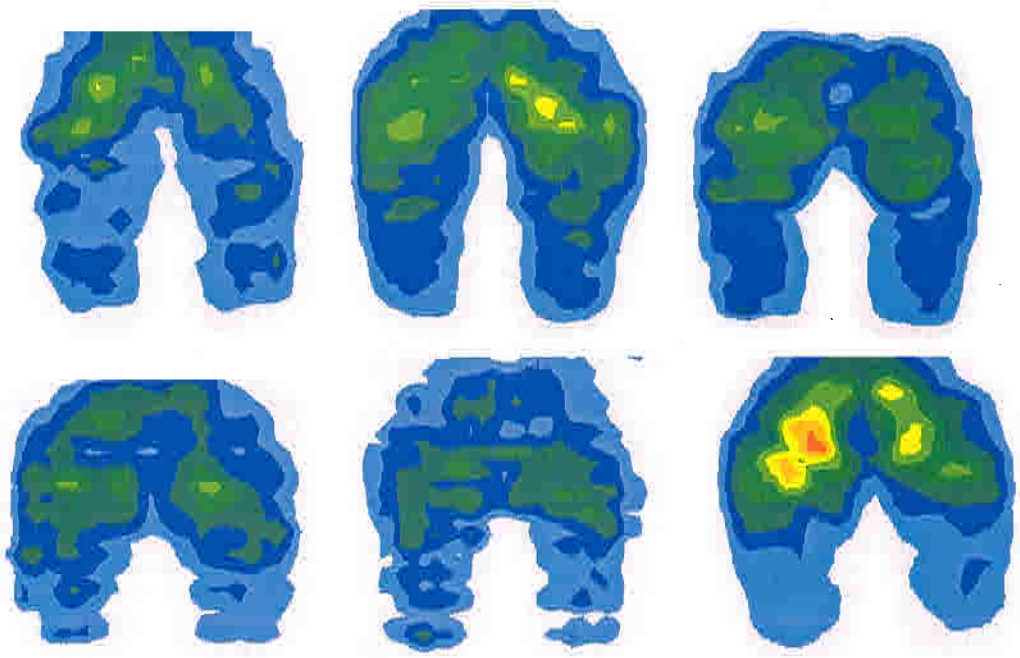
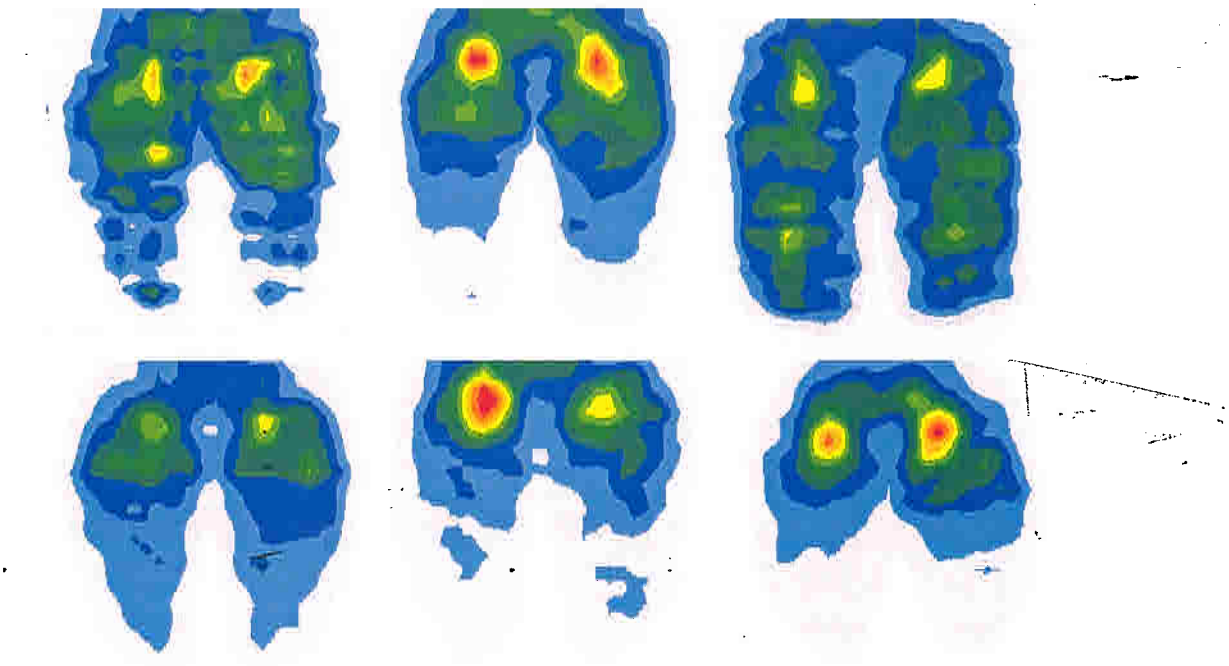


Figure 22: Example 2, comparison of pressure distribution: One subject on six different cushions after 90 minutes



3.2 Subjective experiences of comfort

In the following, scores from the comfort-related statements will be presented. As explained in section 2.2.2, seven statements were read to each subject during testing of each cushion after 10, 30, 50, 70 and finally 90 minutes. Subjects were asked to state to which extent they agreed to the statement read, on a scale from 1-5, where 1 indicates that they fully agree, and 5 that they fully disagree (see appendix 1). During analysis, the reliability of the statement *'I can feel the bottom of the chair through the cushion'* was found to be unacceptable, since the subjects understood the meaning of the statement rather differently. Hence, only judgements of the remaining six statements are included in the presented data.

Tables 3 - 8 reveal the average score of the statements given by the six subjects who were testing the cushions, after each time period and for each cushion. Potential differences between products revealed in the tables will be commented.

In addition, the total average score from all subjects on all products is calculated for each time period, in order to show the longitudinal overall tendencies (independent on type of seat cushion) related to sitting comfort.

Table 3: Average scores on statement 'I am seated comfortably'

Cushion	10 min	30 min	50 min	70 min	90 min
Caresit MFE 600	1.17	1.50	2.00	2.17	2.50
Caresit MFE 601 Split	1.33	1.67	2.00	2.50	2.67
Infinity Airflow	1.33	1.67	2.00	2.67	3.67
Jay Triad	1.00	1.33	1.50	1.67	2.50
Jay2 Deep Contour	1.17	1.33	1.33	1.17	1.50
Kineris HP	1.17	1.33	1.67	2.17	2.17
Roho Nexus Spirit	1.17	1.33	2.00	2.50	3.00
Roho Quadtro	1.17	1.33	1.50	1.67	2.00
Smart Sit 1	1.17	1.33	1.33	1.50	1.50
Smart Sit 2	1.00	1.33	1.50	1.67	1.50
Tempur MED	1.00	1.17	1.67	2.17	3.00
Vicair Academy Adjuster 10	1.00	1.17	1.67	2.50	2.17
Vicair Positioner Plus 10	1.50	2.00	2.50	2.17	2.33
Vital Base Active	1.00	1.00	1.17	2.17	2.33
Vital Base Royal	1.33	1.50	2.33	3.00	3.17
Total average	*1.17*	*1.40*	*1.74*	*2.11*	*2.40*

As shown in table 3, all subjects fully or nearly fully agree that they are seated comfortably after 10 minutes on all cushions. The experience is, however, worsened on all products over time. After 90 minutes there are only three cushions that achieve a judgement score below 2 (agree to some extent). Seven cushions are received a subjective score between 2 and 3, and the remaining five between 3 and 4. The fact that no cushion is given a score over 4, indicates that despite a growing feeling of discomfort, all cushions reveal properties that prevent total discomfort.

The total average scores clearly prove a continuous increase in discomfort as a result of time. Even though there were only a few subjects that reported the highest value of discomfort after 90 minutes, almost all subjects spontaneously expressed their relief when the recordings were done and they were allowed to get up from the chair.

Table 4: Average scores on statment 'The cushion feels too cold'

Cushion	10 min	30 min	50 min	70 min	90 min
Caresit MFE 600	5.00	5.00	5.00	5.00	5.00
Caresit MFE 601 Split	5.00	5.00	5.00	5.00	5.00
Infinity Airflow	5.00	5.00	4.83	4.83	4.83
Jay Triad	5.00	5.00	5.00	5.00	5.00
Jay2 Deep Contour	5.00	5.00	5.00	5.00	5.00
Kineris HP	5.00	5.00	5.00	5.00	5.00
Roho Nexus Spirit	4.83	5.00	5.00	5.00	5.00
Roho Quadtro	5.00	5.00	5.00	5.00	5.00
Smart Sit 1	4.83	4.83	5.00	5.00	5.00
Smart Sit 2	4.50	4.33	4.33	4.50	4.50
Tempur MED	4.67	4.67	4.67	4.67	4.67
Vicair Academy Adjuster 10	4.83	4.50	4.83	4.67	4.67
Vicair Positioner Plus 10	4.50	4.67	4.83	5.00	5.00
Vital Base Active	5.00	4.67	4.67	4.83	5.00
Vital Base Royal	5.00	5.00	5.00	5.00	5.00
Total average	*4.88*	*4.84*	*4.88*	*4.90*	*4.91*

The question whether any of the cushions felt too cold, revealed that this was not a problem for any of the cushions. All subjects fully or almost fully disagreed (average scores ranging from 4.50 - 5) with the statement that the cushion was too cold. Differences between the time periods are minimal, and the total average scores show no real differences.

Table 5: Average scores on the statement 'The cushion feels too warm'

Cushion	10 min	30 min	50 min	70 min	90 min
Caresit MFE 600	4.67	4.50	4.33	4.50	4.00
Caresit MFE 601 Split	5.00	4.83	4.67	4.83	4.83
Infinity Airflow	5.00	4.83	4.67	4.17	4.17
Jay Triad	4.67	4.67	4.67	4.50	4.33
Jay2 Deep Contour	4.17	4.67	4.50	4.33	4.33
Kineris HP	5.00	5.00	5.00	4.83	4.83
Roho Nexus Spirit	5.00	4.83	4.83	4.83	4.67
Roho Quadtro	5.00	5.00	5.00	5.00	5.00
Smart Sit 1	5.00	5.00	5.00	4.83	5.00
Smart Sit 2	5.00	4.83	4.83	4.83	4.83
Tempur MED	4.83	4.83	4.83	4.67	4.67
Vicair Academy Adjuster 10	5.00	5.00	5.00	5.00	4.50
Vicair Positioner Plus 10	5.00	5.00	5.00	4.83	4.83
Vital Base Active	4.83	4.83	4.83	4.83	4.83
Vital Base Royal	5.00	5.00	4.83	4.67	4.67
Total average	*4.88*	*4.86*	*4.80*	*4.71*	*4.63*

The issue of the cushions being too warm did, as for the question of the cushions being too cold, not pose any noteworthy findings. After 90 minutes subjects gave all cushions, except for four, a score between 4.5-5, which implies that they almost fully or fully disagreed to the statement. The four exception scores were respectively 4.00 - 4.17 - 4.33 - 4.33.

The total average shows a slight tendency towards a feeling of increased temperature among subjects, but as indicated above, not to such an extent that they find it uncomfortable.

Table 6: Average scores on the statement 'The cushion feels too soft'

Cushion	10 min	30 min	50 min	70 min	90 min
Caresit MFE 600	4.83	5.00	5.00	5.00	4.83
Caresit MFE 601 Split	4.83	5.00	5.00	5.00	5.00
Infinity Airflow	4.83	4.83	4.67	4.67	4.67
Jay Triad	5.00	5.00	5.00	5.00	5.00
Jay2 Deep Contour	4.83	5.00	5.00	5.00	5.00
Kineris HP	5.00	5.00	5.00	5.00	5.00
Roho Nexus Spirit	5.00	5.00	5.00	5.00	5.00
Roho Quadtro	5.00	5.00	5.00	5.00	5.00
Smart Sit 1	5.00	5.00	5.00	5.00	5.00
Smart Sit 2	4.83	5.00	4.83	4.83	4.67
Tempur MED	5.00	5.00	5.00	5.00	5.00
Vicair Academy Adjuster 10	5.00	5.00	5.00	5.00	5.00
Vicair Positioner Plus 10	5.00	5.00	5.00	5.00	4.83
Vital Base Active	5.00	5.00	5.00	5.00	5.00
Vital Base Royal	4.83	5.00	4.83	4.83	4.67
Total average	*4.93*	*4.99*	*4.96*	*4.96*	*4.91*

None of the cushions were found to be too soft at any time period. All scores range between 4.67 - 5, which indicates that the subjects fully or almost fully disagreed that any of the cushions were too soft. There were, consequently, no relevant differences on the total average scores.

Table 7: Average scores on statement 'The cushion feels too hard'

Cushion	10 min	30 min	50 min	70 min	90 min
Caresit MFE 600	5.00	4.33	4.17	4.17	4.00
Caresit MFE 601 Split	4.50	4.50	4.50	3.67	3.50
Infinity Airflow	4.83	4.67	4.00	3.50	3.17
Jay Triad	4.50	4.17	4.33	4.17	3.67
Jay2 Deep Contour	4.83	4.83	4.50	4.33	4.33
Kineris HP	4.83	4.50	4.17	3.83	4.17
Roho Nexus Spirit	4.67	4.50	3.83	3.33	3.17
Roho Quadtro	4.50	4.83	4.67	4.50	4.50
Smart Sit 1	4.67	4.50	4.33	4.17	4.17
Smart Sit 2	5.00	4.83	4.67	4.00	4.00
Tempur MED	4.33	4.33	3.83	3.17	3.00
Vicair Academy Adjuster 10	4.50	4.33	4.33	3.00	3.00
Vicair Positioner Plus 10	3.83	3.67	3.00	3.00	2.83
Vital Base Active	4.17	4.17	4.00	3.33	2.50
Vital Base Royal	4.50	4.67	4.00	3.50	3.17
Total average	*4.58*	*4.46*	*4.16*	*3.71*	*3.54*

Addressing whether any cushion felt too hard gave more noteworthy findings. After 10 minutes subjects fully or almost fully disagreed that the cushions were too hard in twelve of the cases. For the remaining three, subjects disagreed to some extent. After 90 minutes, subjects only rejected the statement for one single cushion. Five of the remaining cushions were given a score between 3.50 - 4.33, which means that subjects disagreed to some extent that the cushions were too hard. For the remaining products scores ranged from 2.50 - 3.17, indicating that the subjects found the cushions harder than preferable. The total average scores disclose a picture similar to the one found for overall sitting comfort: The cushions feel increasingly harder with time; average scores falling from 4.58 after 10 minutes to 3.54 after 90 minutes.

Table 8: Scores on the statement 'I feel sweatty and sticky'

Cushion	10 min	30 min	50 min	70 min	90 min
Caresit MFE 600	5.00	4.83	4.83	4.83	4.67
Caresit MFE 601 Split	4.83	4.50	4.50	4.50	4.33 *
Infinity Airflow	5.00	4.83	4.67	4.67	4.50 *
Jay Triad	5.00	5.00	5.00	5.00	4.83
Jay2 Deep Contour	4.33	4.33	4.17	4.17	4.17*
Kineris HP	5.00	4.83	4.83	4.83	4.67
Roho Nexus Spirit	5.00	5.00	5.00	4.83	4.67
Roho Quadtro	5.00	4.50	4.50	4.50	4.33 *
Smart Sit 1	5.00	5.00	4.83	4.83	4.67
Smart Sit 2	5.00	5.00	5.00	5.00	5.00
Tempur MED	5.00	5.00	4.67	4.67	4.50
Vicair Academy Adjuster 10	5.00	4.67	5.00	5.00	5.00
Vicair Positioner Plus 10	5.00	5.00	5.00	4.83	4.83
Vital Base Active	5.00	4.83	4.67	4.83	4.17 *
Vital Base Royal	5.00	5.00	4.83	4.50	4.83 *
Total average	*4.94*	*4.82*	*4.77*	*4.73*	*4.61*

Cushions marked with * were tested by a subject who reported feeling sweaty and sticky to a larger extent than any of the other subjects. This was a general tendency, and was independent of the type of cushion she was sitting on. This will have a slightly negative influence on the averaged values for the marked six cushions, and this must be noted when interpreting the results. Bearing that in mind, humidity and moist seem to be of little relevance for the comfort of the subjects. Total average scores drop from 4.94 after 10 minutes to 4.61 after 90 minutes, which is close to a total rejection of the statement.

4 CONCLUDING REMARKS

The pressure mapping recordings in this study revealed that none of the cushions lost their carrying capacity or resilience during the test period. This is a positive finding for all products. There are, nevertheless, considerable differences, both on the frequency distributions over time and the pressure distribution patterns. Differences are observed both between cushions, between individuals sitting on the same cushion, and for each individual sitting on different cushions. These differences were shown to be manifest, and not caused by chance. Hence, our pressure mappings underline that all cushions included in the study reveal different properties, and that no cushion may be characterised as the overall 'best'. Which cushion is best suited for each person is highly individual.

The scores given in response to the general statement, 'I am seated comfortably' clearly prove that the subjects experienced a continuous increase in discomfort as a result of time. The obvious trend in the data implies that it is highly probable that this inclination would continue if the subjects were instructed to remain seated for an even longer period of time. Additional comments provided by the subjects may lead to an impression that they, when giving their scores, actually may have been underestimating their growing discomfort over time. During the first hour of testing, subjects rarely asked any questions about the time. This, however, changed during the last 30 minutes. Subjects then started to ask about the remaining time, and stated that they, in varied degrees, were tired, felt numb, had sensations of pressure, and sometimes even pain in their buttocks and thighs. Even though there were only a few subjects that reported the highest value of discomfort after 90 minutes, almost all subjects expressed spontaneous relief when they were allowed to move at the end of each recording. These findings bear serious consequences if one considers the situation for real-life wheelchair users. If being seated in the same static position for a period of 90 minutes is uncomfortable for our subjects, one can only imagine the negative effect being seated for hours may have on a person with dysfunction in the circulatory-, sensory- and/or locomotive system.

None of the cushions included in the test were judged to be too soft. Rather, subjects seemed to find cushions to be increasingly harder, and to some extent uncomfortably hard during the test period. However, several studies have shown that subjective comfort and pressure measurements are not always well correlated. Temperature seemed not to cause any discomfort during the test period. The pressure mat is, however, obviously a disturbing element to this measure, as well as to the experience of being sweatty and sticky. Thus, these findings should be interpreted with this limitation in mind: Targeted questions could probably reveal properties relating to the *pressure mat* rather than the different underlying cushions and covers. To attain reliable, comparable data on the properties of different cushions and covers related to temperature changes, ventilation and moist transportation over time, additional studies must be performed. These should include both objective tests performed in climate laboratories and subjective statements.

In total, this study confirms, and even enhances, the fact that no seat cushion may be classified as the overall 'best' or well-suited on a general basis. The choice of seat cushion should be considered a highly individual choice, dependent on multiple factors. It must be recommended that a person who needs a seat cushion should be given the opportunity to try *at least* three different types of seat cushion over a longer time period. When selecting the final product, one should also *always* bear in mind additional factors like the usability of the product, practical demands and individual needs of the user, as well as the pressure relieving and distributing properties of the cushion.

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PROTOCOL

Test date	Name	ID-number of testperson	Cushion	Age	Height	Weight	Start rec. (time)	End rec. (time)	Temperature

Give your opinion on the following statements on a scale from 1 – 5, where 1 imply that you *fully agree*, and 5 that you *fully disagree*.

	After 10 min					*After 30 min*					*After 50 min*					*After 70 min*					*After 90 min*				
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
I am seated comfortably																									
The cushion feels too cold																									
The cushion feels too warm																									
I can feel the bottom of the chair through the cushion																									
The cushion feels too soft																									
The cushion feels too hard																									
I feel sweatty and wet																									

Other comments from testperson:

Comments concerning technical issues or other aspects relevant for the recording:

SINTEF

WEBPAGES ALL PARTICIPATING MANUFACTORS/DISTRIBUTORS

AluRehab AS
www.alurehab.com

CareProduct AS
(no web page)
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