

Advantages of Water based gel (WBG)

1. More effective pressure distribution.
Due to the dynamic properties of gel, the fluid contours to the shape of the subject which maximizes the interface area. Since $\text{Force} = \text{Pressure} \times \text{area}$, as the interface area increases, the force decreases.
2. Dynamic properties of WBG provide a changing force field which doesn't allow one force point to be constant. This prevents a high pressure point to be maintained for a continuous extended period. One must remember that the pressure sore formation is dependent on a time force equation. That is, the longer the high force is present, the greater the probability of pressure sore formation.
3. Cooling effect on skin.
To quote the forwarded articles " It is known that soft tissue breakdown occurs when some critical pressure -time relationship is exceeded. But in addition, there are other contributing causes...in particular, an increase in skin temperature is undesirable because there is an accompanying increase in metabolism, which will increase the oxygen requirements in an area of tissue already suffering from poor circulation due to pressure."
4. Improved longevity of the cushion
When one sits on foam there is a concentrated force, generally in the coccyx area which forms a permanent indentation overtime thus making the foam ineffective. With a water based gel overlay, the forces are distributed and therefore the foam remains intact.

Wheelchair Cushion Effect on Skin Temperature, Heat Flux, and Relative Humidity

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ABSTRACT. Stewart SFC, Palmieri V, Cochran GVB: Wheelchair cushion effect on skin temperature, heat flux, and relative humidity. Arch Phys Med Rehabil 61:229-233, 1980.

• For patients subject to decubitus ulcers, wheelchair cushions should be prescribed with knowledge of the cushion's effect on the thermal as well as mechanical environment of the skin. To define thermal effects that may be encountered during routine use, tests were made on 24 commercially available cushions. Skin temperature, heat flux and relative humidity were measured under the ischial tuberosities of a normal 24-year-old man during a 1-hour period of sitting on each cushion. After 1 hour, skin temperatures increased by means of 3.4C and 2.8C on foams and viscoelastic foams and there were slight decreases in heat flux as compared with control values in air. On gels, skin temperatures remained constant and heat flux increased, while water "floatation" pads caused a mean skin temperature decreased of 2.7C along with a marked increase in heat flux. Relative humidity at the skin cushion interface increased by 10.4%, 22.8% and 19.8% on foams, gels and water floatation pads, as compared with room air values. Representative cushions from each of the general types (foam, viscoelastic foam, gel and water floatation) also were subjected to 2-hour tests which indicated the measured parameters continued to change asymptotically.

Protection of soft tissue over the buttock areas is a vital concern to patients who spend many hours daily in a wheelchair. The prevention of decubitus ulcers is essential to the physical and psychological health of the handicapped and is of significant economic importance to the community. Prevention of soft tissue breakdown can be aided by applying knowledge of the causative factors to the care of susceptible persons. Choice of a wheelchair cushion is especially important and can be made only with an understanding of the interaction between a cushion and the skin. This study deals specifically with one aspect of this interaction: the thermal effects of cushions on tissues.

It is known that soft tissue breakdown occurs when some critical pressure-time relationship is exceeded.¹ But, in addition, there are other contributing causes;

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the importance of factors such as shear stress, friction, abrasion, temperature and moisture should not be overlooked in the development of pressure sores.

In particular, an increase in skin temperature is undesirable because there is an accompanying increase in metabolism,² which will increase the oxygen requirements in an area of tissue already suffering from poor circulation due to pressure.³ Also, at elevated skin temperatures, the rate of sweating increases² and will create additional problems in maintaining a dry, cushion-skin interface. The detrimental effect of an increase in moisture content adjacent to the surface of the skin has been shown by tensile tests on excised skin strips in a controlled humidity environment, wherein the tensile strength of the strips decreased 75% with an increase in relative humidity from 10% to 98%.⁴ Skin with such reduced strength may also be more prone to mechanical damage from shear stress or abrasion. In addition, dry skin offers less risk of infection. Long experience in nursing care has led to the empirical rule, "Keep the patient dry."

Despite these observations, little information on temperature and humidity effects of commercially available wheelchair cushions is available. In a recent study, Fisher and associates⁵ conducted sitting experiments measuring temperature only on 5 cushions, but duration was limited to 30 minutes, a short period of time in comparison with a typical period spent in a wheelchair. In an earlier investigation by Brattgård, Carlsöö and Severinsson,⁶ temperature and humidity were measured over periods of 90 minutes on combinations of cushion and cushion covering materials, but specific commercial cushions were not tested.

The purpose of this investigation was to evaluate selected types of commercial cushions for their effect on skin temperature and humidity while sitting. In addition, heat flux was studied as a correlator for temperature.

METHODS

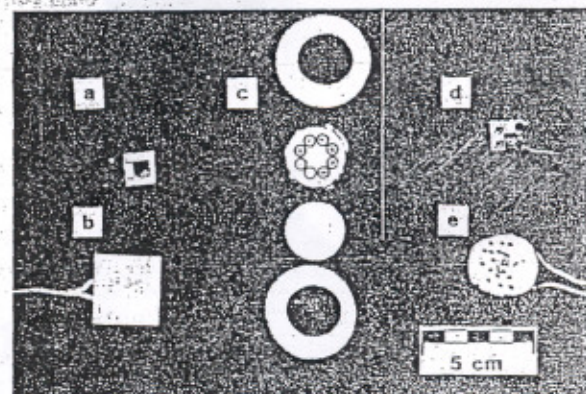
Sitting tests were performed on 24 commercially available wheelchair cushions. The cushions were used with the covers supplied by the manufacturer. A 24-year-old, 60kg man in good health served as the normal subject for all tests. As this individual provided a good repeatable baseline, it was believed that the investigators' efforts could be applied best in obtaining comparative data from larger samples of cushions over longer periods than in dealing with multiple subjects. Loose-fitting cotton hospital trousers were worn, to approximate clothing in a reproducible manner. Each cushion was used in a 1-hour test. In addition, a separate 2-hour test was performed on representatives of each of the 4 basic types of cushions (foam, viscoelastic foam, gel and water "floatation").

Skin temperatures were measured under the left and right ischial tuberosities with thermocouples^a attached to the skin with a single strip of surgical tape. A con-

trol thermocouple was taped to the skin at the right hip, over the greater trochanter. The temperatures measured under the tuberosities while seated were referenced against the control sensor temperature corrected for the mean normal difference in temperature existing between hip and buttock in air. This correction factor (hip temperature \times 0.965) was determined by recording the temperatures at the tuberosities and hip while the subject was standing, with both areas in free air for 30 minutes. Skin temperatures and room temperature were monitored continuously with a 24-channel multipoint recorder.^b Room temperature was maintained at $21.5C \pm 1.0C$.

Heat flux from the skin to the cushion was measured with a heat flux transducer^c taped as near as possible to the temperature sensor under the left ischial tuberosity. Readings were taken at 15-minute intervals with a digital voltmeter. The heat flux transducer is a factory calibrated, differential temperature sensor that generates an output voltage that varies with the temperature gradient, proportional to the heat flux. Changes in this parameter while sitting were referenced against an average value of heat flux from the skin to be the surrounding air ($15kcal/sqm/hr$) determined while standing for 30 minutes with the transducer taped in place, the same procedure as for skin temperature.

Relative humidity (RH) of the skin environment was monitored with an electro-humidity sensor,^d taped near the temperature sensor under the right ischial tuberosity. This sensor was mounted in a ventilated plastic housing to prevent contamination from the skin. The sensor element consists of a small styrene block with an electrically conductive surface layer whose impedance is related to moisture absorption. The element is driven by a constant voltage AC circuit, the current through the element being measured by a digital voltmeter and readings compared to a calibra-



Transducers used in the study: a) thermocouple; b) heat flux sensor; c) exploded view of Humidial humidity sensor—foam ring, Humidial disc, filter disc, foam ring; d) electrohumidity sensor; e) electrohumidity sensor in protective housing.

Table 2: Mean Absolute Differences in Thermal Parameters Between Major Types of Cushions After 1 Hour†

Cushion types A	B	Temperature C	Heat flux kcal/sqm/hr	Relative humidity
Foams	vs Viscoelastic foams	0.6*	4.0*	5.4*
Foams	vs Gels	3.7	50	12.4
Foams	vs Water flotation	6.1	69	9.4
Viscoelastic foams	vs Gels	3.1	46	17.8
Viscoelastic foams	vs Water flotation	5.5	65	14.8*
Gels	vs Water flotation	2.4	19	3.0*

*Not significant

†In all cases, cushion types in column A were warmer than those in column B, but those in B had higher heat flux values to account for the lower temperature. Foam cushions usually demonstrated lower humidity than other types.

the differences in means between types for skin temperature, RH and heat flux are summarized in table 2. These differences were calculated with a t-test at a 99% confidence level.

In general, the foams and viscoelastic foams caused significant increases in skin temperature with a mean change of 3.4C over the initial control reading in air for the foams, accompanied by a reduction in heat flux of 9 kcal/sqm/hr. On gel cushions, temperatures remained relatively constant while heat flux increased a mean of 41 kcal/sqm/hr over the initial air value. Water flotation pads caused significant drops in temperature at the skin with a mean of 2.7C below the control accompanied by a mean increase in heat flux of 60 kcal/sqm/hr. Increases in relative humidity at the skin interface averaging 10% over room values were

noted on foam cushions, but increases averaging 23% occurred on gels and 20% on water cushions.

In the 2-hour tests, the findings of the 1-hour series were confirmed and trends established during the 1st hour tended to continue, although the rate of change diminished. Changes in the measured parameters over a 2-hour test period are shown for representative cushions of each major type in table 3.

DISCUSSION

This study has highlighted marked differences among cushions in terms of their ability to handle heat and humidity beneath seated patients. Naturally, the behavior of each cushion is influenced strongly by the covering used as well as by the primary structural material.

In terms of cushion groups, foams and viscoelastic foam tend to be hot, to increase the skin temperature by several degrees because the foam materials themselves and the air entrapped within tend to be poor absorbers and conductors of heat. In fact, the heat flux at the interface is lower than in air. As the body heat is not removed from the interface, the temperature rises. On the other hand, humidity does not rise as much on most foam cushions with a porous cover, because the open cell structure of the foams tested provides a pathway through which moisture can diffuse. Movements of a patient while sitting would tend to increase this action. The only foam cushion that displayed a relatively large increase in relative humidity was one that had a vinyl cover. The foam cushions demonstrate that there is not necessarily a clear relationship between skin temperature and the moisture content of the skin's environment.

Gel pads, as a group, showed a considerably higher heat flux than foam, enough to maintain the skin temperatures relatively constant. Here, the effect probably

Table 3: Changes in Thermal Parameters for Representatives of Each Cushion Type over 2-hour Test Period

Cushion	Minutes	Change in skin temperature C			Change in heat flux kcal/sqm/hr			Increase in relative humidity % RH		
		30	60	120	30	60	120	30	60	120
Foam type										
Rogers 1836		1.45	2.6	3.4	-1.8	-8.0	-8.0	-	-	15
perforated Foam #1		3.3	4.3	4.9	-1.8	-1.8	-8.0	-	-	9.5
Viscoelastic foam type										
Alimed 164-S		1.2	2.3	3.25	5.0	-1.8	-3.0	-	-	17
Gel type										
Resion Flo Pad 1565		-1.5	0.85	0.1	51	31	18	16	-	39
E & J WC-17		-1.8	-1.4	-0.8	64	51	43	33	23	47
Water flotation type										
Med Pro H ₂ O		-3.8	-3.9	-3.4	91	78	58	24	14	36
Special type										
Roho Balloon		1.65	2.65	3.75	12	5.0	5	25	15	34.5

is due to the relatively high specific heat of the gel material. The rate of heat transfer diminished by the end of 2 hours indicating that the heat reservoir was beginning to fill so that skin temperatures might well begin to rise over longer periods of unrelieved sitting. Humidity values increased considerably on the gels because of the nonporous nature of their construction. Clinically, gel cushions would be indicated over the foam variety whenever increases in skin temperature may be considered inadvisable. In these cases, the patient should be advised to restrict sitting periods on the same cushion to a maximum of 3 hours, to permit cooling of the gel.

Water floatation pads provided significant drops in skin temperature associated with high heat flux. The primary factor here is high specific heat of water combined with good conduction and mechanical circulation of the fluid. From a clinical standpoint, some patients actually describe water cushions as cold, while "water beds" are known to require heating devices. While water cushions may be considered when it may be therapeutically desirable to reduce skin temperature, patient tolerance is a factor that always deserves consideration. The humidity elevations associated with water cushions again appear to be related to the nonporous nature of the cushion structure.

Regarding the 2 cushions that did not fall into a standard type, the Styrofoam bead-filled unit produced a rise in skin temperature associated with low heat flux and increased humidity. Similar effects were produced by the "balloon" (airfilled) cushion. In the latter case, the heat flux probably was restricted by both the low specific heat of the air and the insulating effects of the rubber. With respect to humidity, the tufted balloon construction may allow for some air circulation while the patient moves, but the tufts are squeezed together during sitting so that the effect is the same as sitting on a cushion of an impermeable material.

The results of this investigation support and extend the findings of 2 previous studies.^{5,6} As with the mechanical properties of cushions,^{8,9} the thermal properties vary with the type and specific design of each pad. Often, a cushion providing desirable performance in 1 aspect, such as temperature control, gives inadequate performance in another, such as humidity control. For noncritical applications, the relatively high skin temperature produced by foams can be accepted because of the relatively low humidity, convenience, low cost and satisfactory mechanical performance afforded by these cushions. For critical applications where skin temperatures must be controlled, gels are the obvious choice although the tendency to increase humidity becomes a drawback. As has been suggested elsewhere,^{8,9} the answer may lie in developing layered, combination, cushions to improve thermal, mechanical or other aspects of performance. The moisture control properties of gels might be improved by placing a separate top layer of porous foam or other material over the gel or under the gel.

with the whole enclosed by a suitable porous cover. The extra layer necessarily would have to be selected so that it would not affect heat flux significantly, but would permit drying by air pumping and circulation as the patient moved.

Once again, it is clear that no given cushion is ideal from all standpoints. For difficult problems, the proper cushion or cushion combination must be prescribed for the individual patient. In this process, not only thermal aspects but mechanical properties as well should be considered. Finally, it is important not to confuse the results of this study, based on interface measurements during sitting, with those of thermography which probably reflect primarily the reaction at skin circulation to sitting forces.

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Suppliers

- a. Hy-Cal Engineering Model TC-2345 Thermocouples, Hy-Cal Engineering, 12105 Los Nietos Road, Santa Fe Springs, CA 90670
- b. Honeywell Elektronik Model 16, 474 Springfield Ave., Westfield, NJ 07090
- c. Thermonetics Model HFT-A heat flux transducer, Thermonetics Corporation, 1028 Garnet Avenue, PO Box 9112, San Diego, CA 92109
- d. Phys-Chemical Research Corporation Model 55 electro-humidity sensor, Phys-Chemical Research Corporation, 36 West 20 Street, New York, NY 10011
- e. Humidial Model HHH-20-90 humidity sensor, Humidial Corporation, 465 Mt. Vernon Avenue, PO Box 464, Colton, CA 92324
- f. Millipore 10.0μ Teflon filter disc, Millipore Corporation, Bedford, MA 01730

with
stretchable,
moisture
absorbent
cover
padding is
corrected.

See
comment
re: cover
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tion curve to determine relative humidity; this sensor was readable only above 50% RH.

Relative humidity also was measured with a chemical sensor* taped near the thermocouple under the left ischial tuberosity. The actual sensor consists of a 2.5-cm disc of blotting paper labelled with RH readings of 20% to 90% in 10% increments. Each of the labels is impregnated with a spot of cobaltous chloride solution in a concentration that changes from blue to pink at the specified humidity. Because a lavender color indicates an intermediate value of relative humidity, this sensor can be read to the nearest 5%. For use beneath seated patients, the sensors were prepared according to Trandel,⁷ who designed a sandwich unit with the disc placed between 2 latex, open-cell foam rings fabricated from self-adhesive electrode pads. A filter disc⁸ was inserted between the humidity sensor disc and the foam ring facing the skin to protect the sensor from skin contamination. This sensor was read by visual inspection at the conclusion of each 1 or 2-hour

test. Both types of humidity sensors were calibrated by suspending them in sealed containers over distilled water/glycerine solutions known to produce specific partial pressures of water vapor. Room air humidity varied in the range of 36%-44% RH; values for the seated subject were referenced against the room humidity on the day of measurement.

All sensors employed in these tests are shown in the figure.

RESULTS

Changes in the measured parameters at the end of 1-hour tests on all the 24 cushions tested are tabulated in table 1. The ischial tuberosity temperature and humidity readings represent averages from the 2 buttocks. No statistically significant differences were found between readings from the 2 temperature sensors, or the humidity readings from the 2 different sensors, when evaluated over all the cushion tests at a 99% level of confidence. For comparison of the basic types of cushions,

Table 1: Changes in Thermal Parameters After 1 Hour*

	Change in skin temperature C	Change in heat flux kcal/sqm/hr	Increase in relative humidity % RH
Foam type cushions			
Rogers 1836	+3.5	-16	+3
Rogers 1834	4.45	-8	3
Rogers 2330 (scored)	3.7	-8	9
3040			
Rogers 2330	2.8	-3	3
3040			
Perforated Foam #1	3.25	-16	8
Perforated Foam #2	3.8	-16	2
"Egg Crate" Contour	3.4	-3	18
Scimedics L	3.2	-16	6
Scimedics SR	2.95	-3	8
E & J Tri Pad	3.8	-16	7
Telley Scimedics	2.7	-3	29
Posture Foam			
MEAN (foam type)	3.4 (±0.7)	-9 (±6)	10.4 (±6.1)
"Viscoelastic foam" type cushions			
Allmed 164-S	+2.4	-3	+3
Allmed 164-M	3.15	-8	7
MEAN (viscoelastic foam types)	+2.8 (±0.4)	NS	NS
Gel type cushions			
Reston Flo Pad 1565	-0.25	+38	+26
Bioclinic 516 Flo Pad	-0.35	30	15
Stryker Flo Pad	-0.3	38	25
Action Flo Pad	-0.1	51	14.5
E & J WC-17	-0.8	43	29
Bioclinic Rear Guard	-0.05	38	26
MEAN (gel types)	-0.3 (±0.5)	+41 (±7)	+22.8 (±6.8)
Water flotation type cushions			
Bioclinic	-1.75	+62	+17
Lumex Aqua-Ease	1.55	51	22.5
Medpro H ₂ O	-4.3	65	20
MEAN (water flotation types)	-2.7 (±1.3)	+60 (±6)	+19.8 (±3.0)
Special type cushions			
Decubitex (Styrofoam bead-filled)	1.4	-16	20.5
Roho Balloon (multiple air bladder)	2.65	5	25

*The figures shown represent changes in the initial control skin temperature in air, heat flux in air, and room relative humidity on the day of testing. Standard deviations are given following the means.