

Technical Considerations

Seat Cushion Selection

by Martin W. Ferguson-Pell, PhD

Dr. Ferguson-Pell is Director, Center for Rehabilitation Technology and Chief of Rehabilitation Engineering Unit, Orthopedic Engineering and Research Center, Helen Hayes Hospital, West Haverstraw, NY.

INTRODUCTION

It is natural to ask why the selection of wheelchair cushions warrants any detailed discussion. One would assume that the two or three cushions which do the job well for most people would survive the rigors of the medical marketplace. Surprisingly, this is not the case: engineers and others have not developed a universal cushion that meets the needs of the majority of users. In addition to different wheelchair cushions on the market, there are many custom designs which offer hundreds of options. Usually only one or two will “do the job well” for a given client. As a result, clinicians face the task of matching an individual’s needs with the properties of a confusing array of available cushions. To make matters worse, our basic knowledge of how the seated subject and the cushion mechanically interact is very limited, owing to the mechanical complexity of the tissues involved. Therefore, a scientific approach to designing cushions, and instruments to help fit them has been slow to develop, but real progress has been made in the last decade.

A wealth of information does exist through the clinical observations and experience of expert cushion prescribers. But a central data/knowledge base or any other mechanism allowing us to learn through collective experience, has not yet been developed. Thus, much of the advice given to therapists new to this field is anecdotal and parochial.

The objective of this chapter is to give practical guidelines and necessary background for approaching the problem in a systematic and rational way.

The primary role of a wheelchair cushion is to provide an effective platform from which the user may perform a wide range of tasks. It is difficult to work at a table or desk or to propel the wheelchair, if the sling seat is the only support. The wheelchair cushion also improves comfort, aids posture, and absorbs shock during propulsion over uneven surfaces. For many, the cushion performs a crucial function by reducing the concentration of pressure in tissues, thereby helping to prevent the formation of pressure sores.

Selecting a seat cushion should be considered an integral part of the process of prescribing the correct wheelchair. Failure to recognize that the wheelchair and the seat cushion should be prescribed at the same time can waste human and material resources, and result in a far-from-optimal seating system. All too often, the seat cushion (and other critical “accessories”) are prescribed as an afterthought; choice is then restricted to accommodate constraints introduced by the dimensions of the wheelchair.

Some wheelchair users with skeletal deformity or very limited postural control, require seat inserts that help control the position and stability of the trunk and hips (36). Seat inserts frequently require special components and shapes. Recent developments using modular components are expanding on

the traditional fabrication techniques involving plywood and foam construction. Custom-shaped shells can now be produced by: 1) vacuum forming of sheet plastics; 2) resin-bonded vacuum consolidation of glass or styrofoam beads; 3) forming shapable matrices of lockable plastic components; and, 4) foam molding may be performed around a user while he/she is held in an optimum sitting position in the wheelchair. In a few hours, these methods can provide a finished custom-formed postural support which intimately follows complex curvatures and may also help to reduce localized pressure (19).

Specialized seat inserts are normally prescribed by seating specialists who have received comprehensive training in clinical evaluation, the biomechanics of sitting, and fabrication techniques. However, some of the basic principles used in prescribing sophisticated seat inserts also apply to prescribing wheelchair cushions. A review of these principles will certainly be useful.

The information in this chapter is organized into three main categories:

- A. *General Principles*
- B. *Evaluating the Client*
- C. *Some Useful Techniques for Matching Cushion with Client*

with the addition of two short categories:

- D. *Wheelchair Cushion Fitting Clinics*, outlining what is needed to establish an effective clinic; and
- E. *CUSHFIT*, describing an expert system program that guides the novice through the fitting procedure.

A. GENERAL PRINCIPLES

When we sit on a cushion, a number of interacting factors determine whether it is comfortable, functional, and clinically safe. Many of these factors are interrelated; some factors are attributed to the properties of the cushion, and others due to the characteristics and needs of the user.

Factors that affect comfort include:

- 1) poor distribution of stresses in soft tissues
- 2) moisture accumulation
- 3) heat accumulation and loss
- 4) compromised stability.

Factors that determine functionality include:

- 1) stability provided
- 2) weight of the cushion
- 3) frictional properties of the cushion and cover
- 4) cushion thickness
- 5) appearance
- 6) cost
- 7) durability and the need for user maintenance.

Factors that determine clinical safety include:

- 1) poor distribution of stresses on soft tissues
- 2) stability provided
- 3) frictional properties of the cushion and cover
- 4) moisture accumulation
- 5) heat accumulation and loss
- 6) durability and the need for user maintenance
- 7) flammability.

POOR DISTRIBUTION OF STRESSES IN SOFT TISSUES

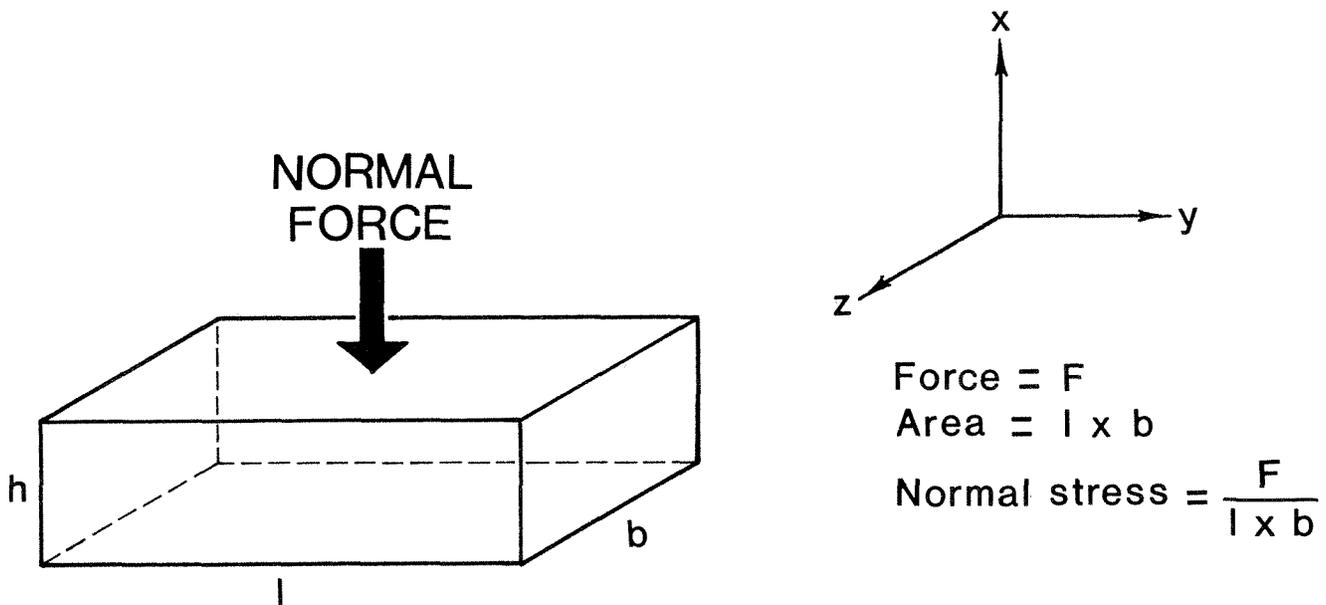
Stress is defined as force divided by the area over which it acts. Higher stresses occur if either the force acting over a given area becomes larger or if a given force acts over a smaller area (**Figures 1a and 1b**).

Causes

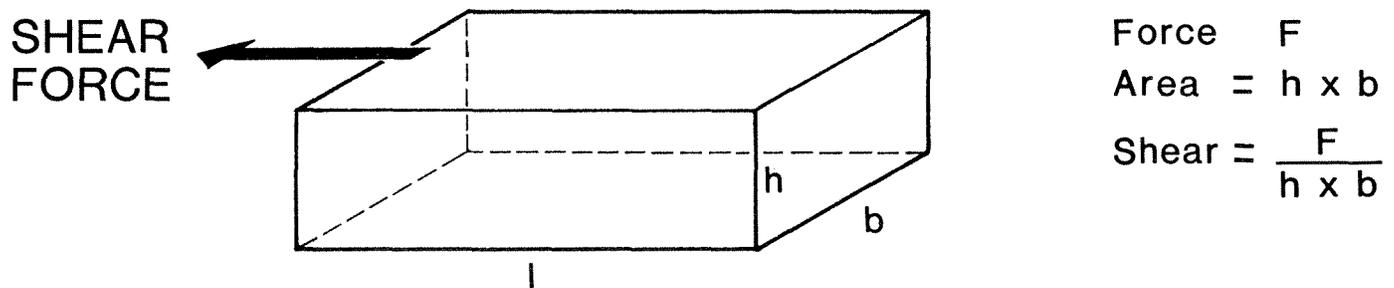
Localized stresses in soft tissues are an inevitable consequence of sitting. Only when we are suspended in water or are weightless in space, are the stresses on our tissues evenly distributed. When our body weight is supported on a solid surface such as a cushion, localized stresses are generated which compress and deform the soft tissues. The changes in the shape of the soft tissues result in occlusion of blood vessels and lymphatics, and stimulate nerve endings which may signal discomfort to the central nervous system.

The stresses can be divided into two groups: those that act perpendicular to the skin, called normal stresses (in everyday speech we use the term pressure) and those that act parallel to the skin, called shear stresses.

When a person is in the sitting position in a wheelchair, the total force acting on the buttocks

**Figure 1a.**

Normal stress will be increased if F is made larger or if the area is made smaller. Normal stress causes materials to compress (compression) or expand (tension) without significant change in shape.

**Figure 1b.**

Shear stress will be increased if F is made larger or if the area over which it acts is made smaller. Shear stresses cause the shape of materials to be changed without significant change in thickness.

and thighs is body weight minus the supporting forces of the footrest and backrest. The greatest proportion of body weight, when sitting, is therefore supported by the area over the ischial tuberosities (ITs).

Bone resists even large forces with barely perceptible deformation. Muscle and fat are far more vulnerable because they deform more readily, causing blood vessels to be occluded. The force due to body weight, when sitting, is imposed by the ITs on the gluteal muscles and fat, which become deformed due to the compressive force. In addition to the force of the ITs and the amount of tissue supporting them, tissue stiffness or tone also determines how much deformation (and therefore dam-

age potential) is developed in the fat and muscle. Wheelchair users with little muscle tone in their gluteal area are less able to resist tissue deformation, and are therefore more vulnerable to discomfort and tissue damage.

It is important to note that heavy individuals are not necessarily more vulnerable to tissue breakdown (17). They normally have more fat and muscle padding, which compensate for the additional body weight that has to be supported. At greater risk is an emaciated person with flaccid gluteal tissues. The combination of inadequate padding and poor muscle tone produces higher than average deformation in the tissues that remain. Those who have lost

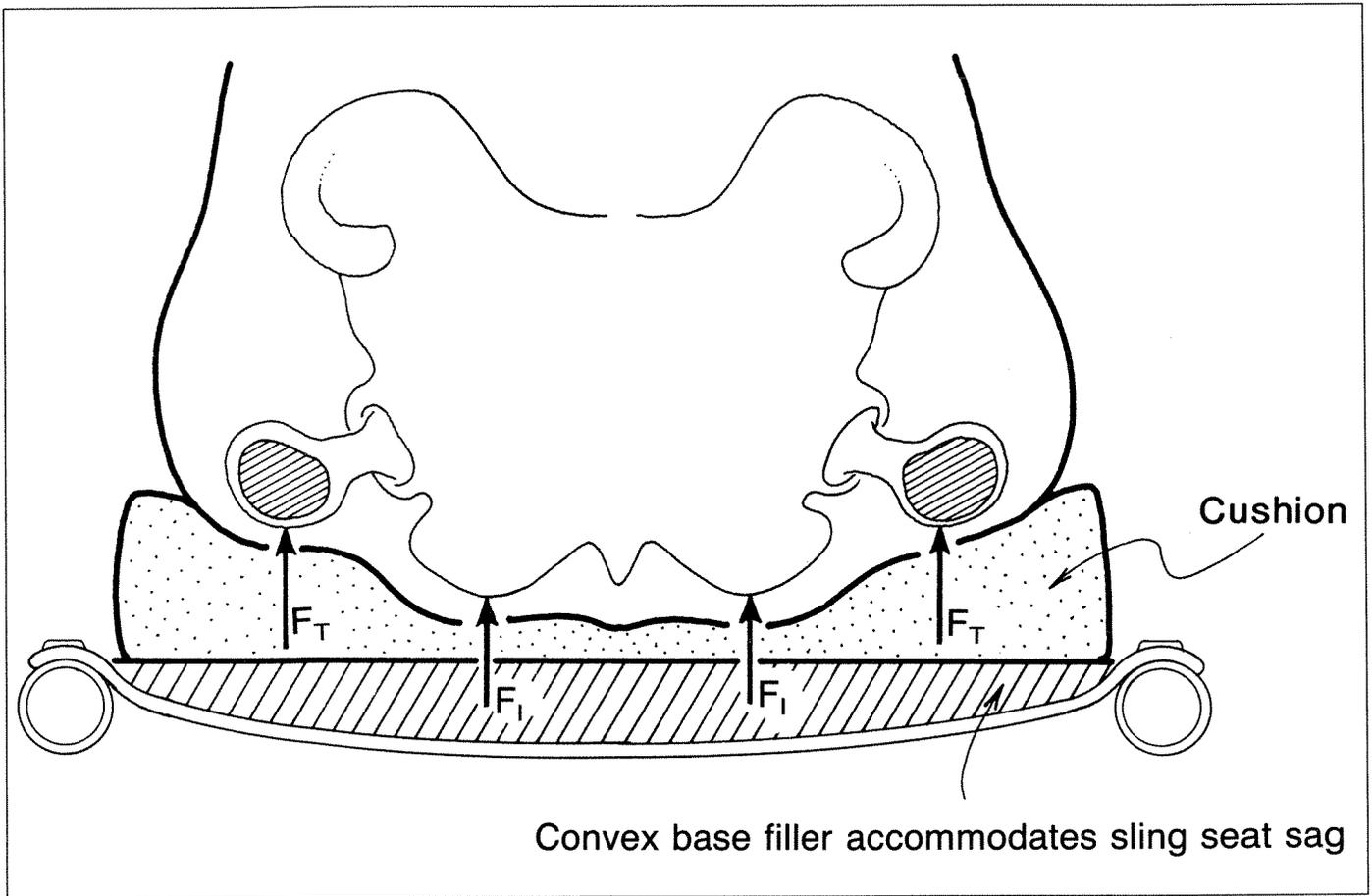


Figure 2.

Shaped cushions help share the supporting forces F_I and F_T more equally between the ischial tuberosities (F_I) and the trochanters (F_T). On cushions with no shaping F_I is considerably larger than F_T and the ITs have to compress the cushion nearly 2 inches before the trochanters make contact.

tissue overlying the ITs due to previous pressure sores are also particularly vulnerable.

Prevention

Stresses in the soft tissues are not usually evenly distributed, and are thought to be greatest in the muscle close to the ITs, the area in which pressure sores seem to start. Necrosis migrates outward to the skin as cell constituents are released and cause damage to nearby compromised tissue.

If weightbearing can be shared equally by the ITs and the nearby lateral posterior aspect of the trochanters, the force at each IT is half of that when only the ITs are loaded, and more soft tissues can share the burden. Weight distribution is, therefore, an important principle used for designing cushions that are shaped to encourage trochanteric and thigh support (**Figure 2**).

MOISTURE ACCUMULATION

Moisture accumulation results in discomfort and, in some cases, an increased risk of soft tissue damage. Many factors determine the causes and prevention of moisture accumulation.

Causes

Generation of excessive quantities of heat. Sweat is normally generated to assist in the thermoregulation of the body by the evaporation of moisture to cool the surface of the skin. Normally, sweating is suppressed locally by pressure. Following spinal cord injury, however, sweating can occur in an uncontrolled manner independent of thermoregulation. The reduction of pressure by use of sophisticated cushion systems can, in effect, reduce suppression of sweating due to pressure, and thus

pose potential difficulties in keeping the skin dry and free from damage due to maceration.

Poor exchange of air. If there is poor exchange of air in the supported area and the supported area is thermally insulated by the cushion, the interface temperature can exceed 38 degrees Centigrade, whereupon sweating increases rapidly with increasing temperature.

Use of impermeable covers. Moisture accumulation can also occur if materials in close contact with the skin do not "breathe." Vapor-impermeable covers prevent moisture-laden air from being diluted by drier air, thereby preventing newly-formed sweat from evaporating or being absorbed. Furthermore, because sweat is not being evaporated, natural environmental cooling cannot occur, resulting in more heat build-up and more sweating.

Measurement

Continuous humidity or moisture monitors have not proved to be reliable in measuring the microclimate between the skin and cushion. A simple moisture-sensing patch is available* that has been used successfully in research projects (14,35). We are not aware of any centers using humidity sensors in routine clinical evaluation: common sense, direct client feedback, and experience seem to be adequate.

Prevention

Methods for preventing moisture build-up include the use of cushion and cover materials that encourage air exchange between the cushion and skin. Cushions with good heat dissipation characteristics help to reduce moisture build-up, if they are appropriately covered with absorbent materials like sheepskin or jersey knit fabrics. Wearing cotton/flannel underwear also helps to reduce moisture build-up.

Water vapor permeability, absorbency, heat capacity, and thermal insulation of materials used in cushions are readily measured in the laboratory, but are rarely quoted by manufacturers. As we become more sophisticated and learn how to apply this information, disclosure of such data should become more routine.

Some cushions naturally pump air that is trapped in their structure when compressed (e.g., foams). The Jay cushion may now be ordered with an Air-exchange cover that uses this principle (**Figure 3**). This effect can contribute to maintaining comfortable moisture levels at the cushion/skin interface, if the cushion is fitted with an air-permeable cover. Air exchange is an added incentive to encourage "push-ups," even for those who are not particularly at risk of developing pressure sores, but who do experience discomfort due to moisture accumulation.

HEAT ACCUMULATION AND LOSS

Causes

When a warm buttock makes contact with a cold cushion, the buttock will cool down and the cushion will warm up until the cushion-tissue interface reaches an equilibrium temperature. Some cushions (e.g., gels) feel colder than others (e.g., foam) because fluids and gels conduct heat more rapidly than foams and air.

Another important thermal property of a cushion is its heat capacity, or the amount of heat required to raise its temperature one degree. Heat capacity varies with the mass of the cushion and the type of material.

Measurement

In principle, heat accumulation can be measured using thermistors or thermocouples. However, several problems reduce practicability for routine clinical evaluation. As indicated in the studies of Stewart *et al.* (35) and Ferguson-Pell *et al.* (14) equilibrium of skin temperature requires sitting for more than an hour.

It is still unclear how we might quantify heat build-up for clinical interpretation. We could measure the equilibrium temperature, but the transitory coolness of a cushion that has not reached equilibrium may give considerable relief. We could measure the area under the time-temperature plot for a typical sitting period, but this requires a fairly sophisticated data-logging system. Similarly, we could measure the time taken to reach a critical skin temperature—38 degrees Centigrade—above which sweating becomes increasingly profuse in able-

*Humidial Model HHH-20-90, Humidian Corp. 465 Mt. Vernon Ave., P.O. Box 464, Colton, CA 92324.

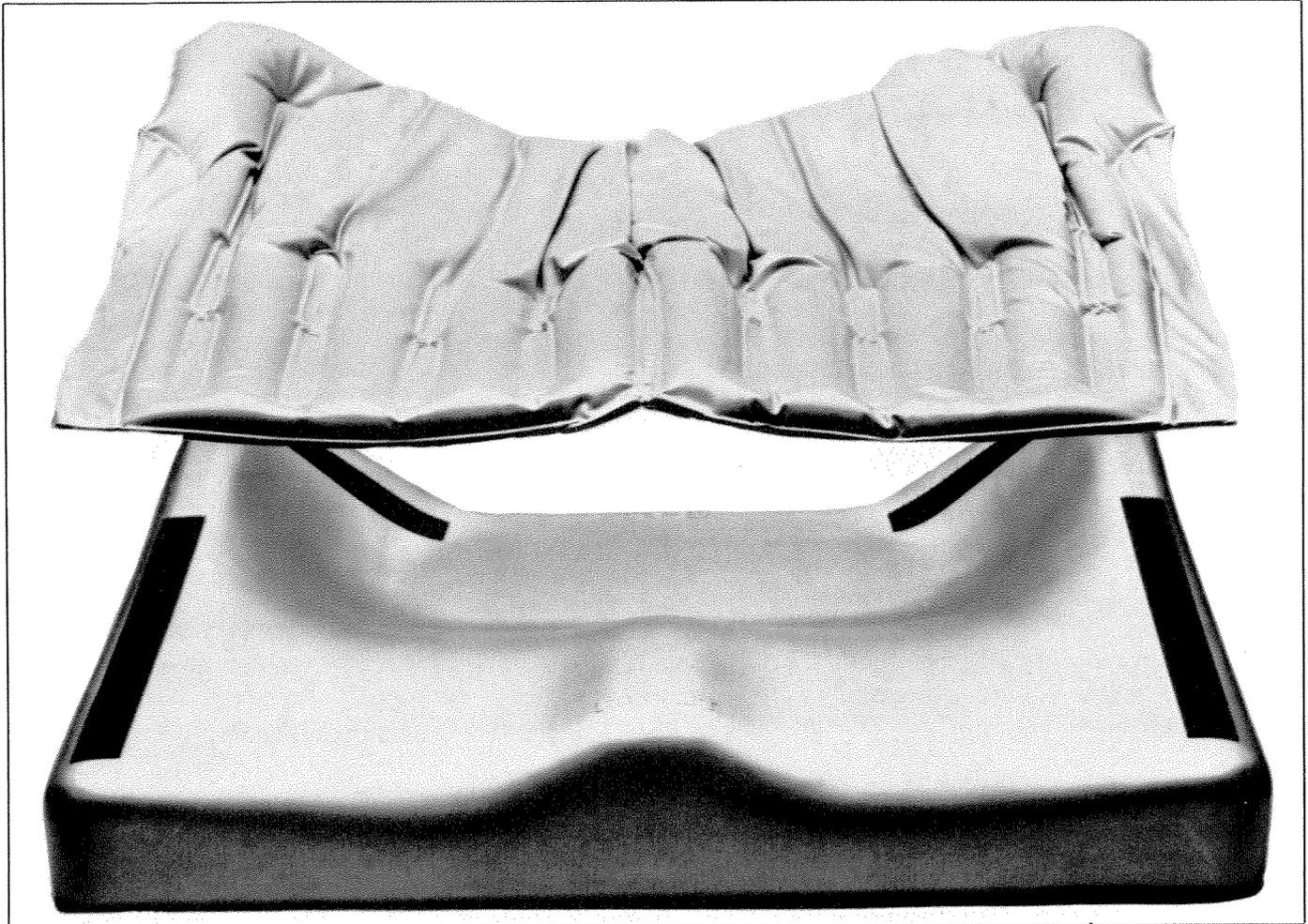


Figure 3.
“Standard” Jay cushion with cover removed.

bodied individuals. Whichever method is used, prolonged monitoring is required, preferably over a range of environmental temperatures. In practice, it is sufficient to predict how different cushions respond to heat build-up by knowing their thermal properties as reported in the studies of Stewart *et al.* (35), Ferguson-Pell *et al.* (14), and **Figure 4**.

Prevention

Foams are poor conductors of heat and have a low heat capacity. A thin layer of foam (plus cover) warms up to skin temperature when one sits on it, but does not draw much heat from the body's tissues. In warm environments, or during physical exercise, the body attempts to lose heat but is prevented from doing so in the buttocks area due to

the insulating foam of the cushion. This region may therefore begin to heat, resulting in uncomfortable dampness.

On the other hand, gels and fluid-filled cushions are moderate conductors of heat and have a high heat capacity. They drain heat from the buttocks and continue to do so for a long time (**Figure 4**). For energetic wheelchair users, the thermal properties of the gel help to dissipate metabolic heat. Gel cushions are also beneficial in warm environments if effective water vapor and sweat removal can be assured. However, in cold environments or for weak individuals who have difficulty in staying warm, these cushions make additional demands on the metabolic system. Furthermore, gels and fluid-filled cushions are heavy

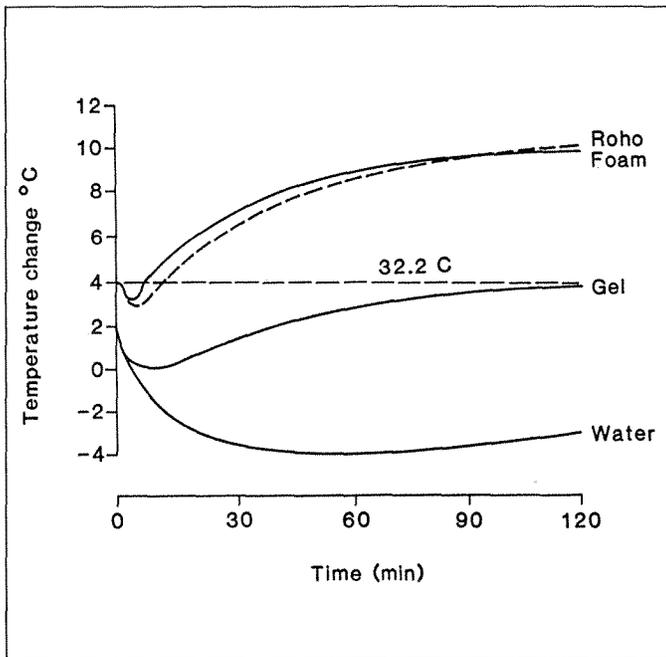


Figure 4.

Changes in skin temperature and moisture content of the buttock/cushion interface for an able-bodied subject for 2 hours continuous sitting. (Reproduced with permission, Oxford University Press, 1986.)

(up to 35 pounds), which can reduce wheelchair performance as well as present problems in stowing the wheelchairs in the car. Some cushions are designed to obtain the best properties of both materials by using a modular approach, with the gel close to the skin, and foam for the bulk of the cushion. Because the mass of the gel is relatively small, the heat capacity is smaller than a total gel cushion. It achieves less cooling with less metabolic heat drain. Studies completed by Stewart *et al.* (35) and Ferguson-Pell (14) discuss experiments on the thermal properties of cushions in detail.

COMPROMISED STABILITY

The effect that the cushion has on stability, real or perceived, can be critical—especially for users with poor trunk control.

Causes

A number of mechanical properties of the cushion influence the stability of the support surface. The ability of the cushion to deform, both in

direct compression (vertical loading) and in shear, must be considered.

Highly compressible cushions offer very little resistance to body weight and tend to function like an overcompressed spring. If one rides over a bump in a wheelchair the “hardness” of the sling seat can be felt through the cushion. Overcompressed cushions are said to “bottom out.”

At the other extreme, incompressible cushions are ineffective in preventing pressure localization. Because they are less compressed, the user often feels as if he/she is sitting on a cushion that is too thick. In addition, the cushion may appear to be moderately deformable in shear, and may feel unstable during manual propulsion.

Cushions that fall between these two extremes have advantages, such as improved pressure distribution, but may also feel “springy.” Compromises between cushion stability and pressure distributing capacity often have to be made in practice—usually by accepting a small increase in the accepted pressure over bony areas.

Material thickness can influence the sense of instability, the cushion’s compressibility, and its pressure distributing properties.

Measurement

At present we are unaware of any routine method to measure trunk stability. We rely upon direct feedback from the user. Persons with spinal lesions at a high level often have acute awareness of their trunk stability that is far more subtle and complex than position measurement systems are able to detect.

In the laboratory, we test the effectiveness of a material or cushion in absorbing impact energy by measuring hysteresis, which is represented by the area between the load-deformation curves for loading and unloading conditions (Figure 5). Hysteresis is normally expressed as a percentage, representing the energy lost during the loading/unloading cycle.

Prevention

Deformability and cushion thickness alone do not control the destabilization of the user. Some cushions have the capacity to absorb energy when they are deformed. Gels, fluid-filled cushions, some foam cushions, and simple air pillows behave fairly elastically when sat upon, and create a feeling of instability during propulsion or when riding over rough ground. Because they are elastic, they tend to

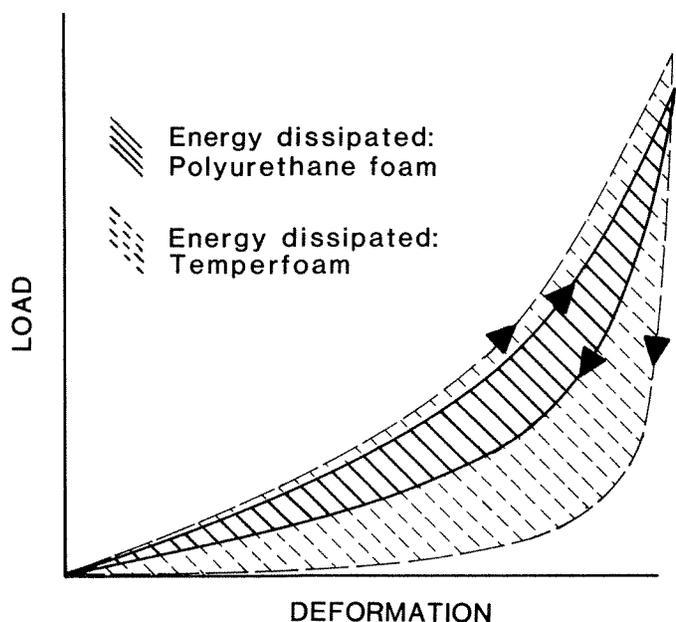


Figure 5.

Energy dissipation of cushion materials can be determined by performing a simple mechanized test. The area within the load-deformation curve when the sample is loaded and then unloaded provides a measure of energy dissipation. The greater the shaded area the more energy is dissipated by the cushion.

transmit the energy of dynamic loading to the body via the gluteal tissues for dissipation.

Viscoelastic materials (Temperfoam is an example) have the capacity to absorb energy on impact, like shock absorbers, which results in a real and perceived sense of stability. Viscoelastic materials are time-dependent, their stiffness depending upon the rate of loading. Impact loads do not cause as much cushion deformation as slowly applied loads, and may therefore tend to produce high, localized, instantaneous pressure. Another consideration is that because viscoelastic materials compress increasingly over time, after an hour of sitting they may bottom out, producing areas of localized pressure.

The deformation of these materials is also dependent upon the temperature of the material. When cold, they may feel very hard until softened by body heat. When very warm, viscoelastic foams easily bottom out. Caution should be exercised in using these materials above or below the normal room temperature range.

Some air-filled and water-filled cushions behave viscously, too. Roho cushions, for example, consist of interconnected air bladders (**Figures 6a and 6b**).



Figure 6a.

Roho wheelchair cushions (upper "normal" and lower "low" profiles).

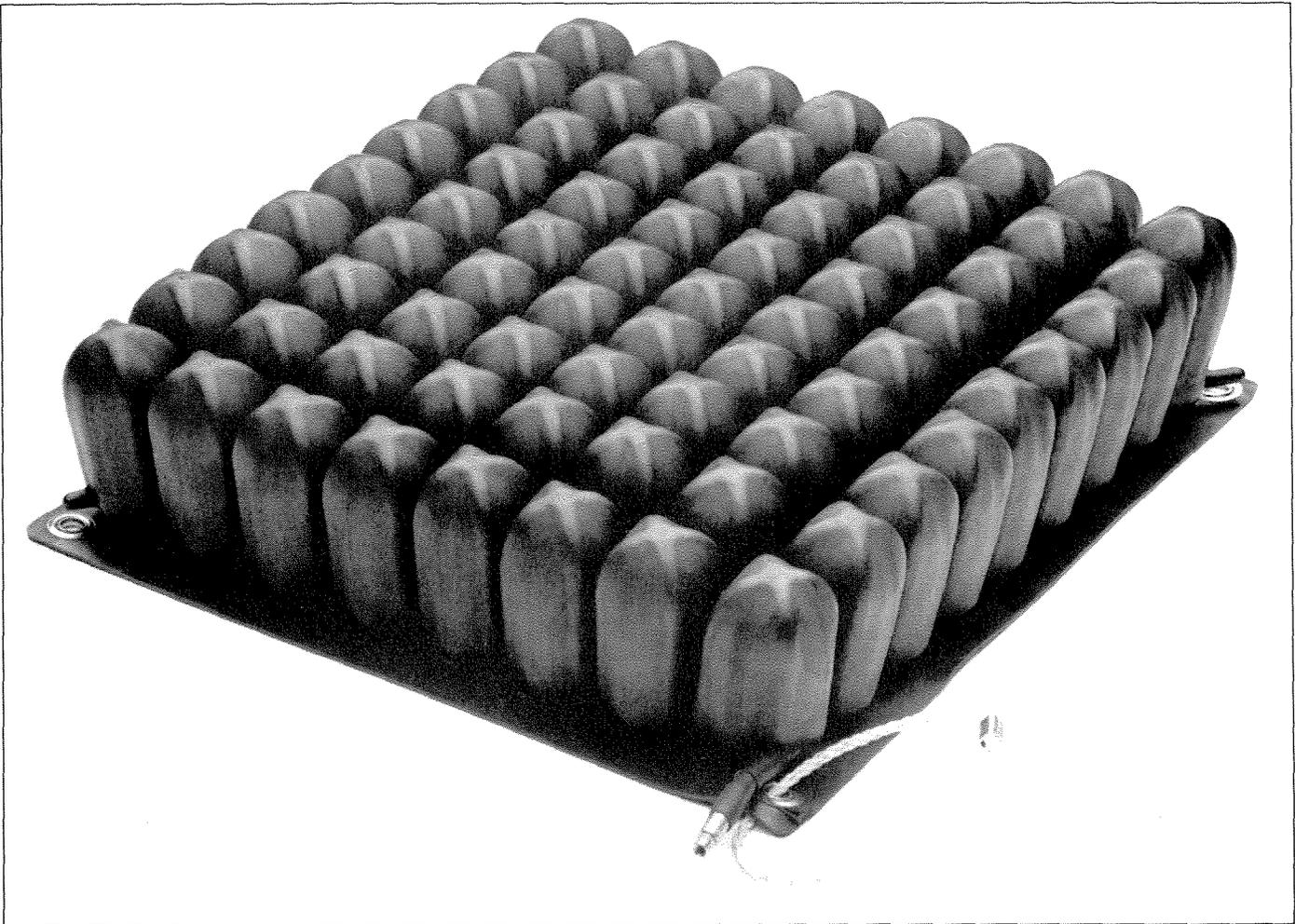


Figure 6b.
Roho "high" profile cushion.

If a sudden localized force is applied, the air in the loaded cells is forced into neighboring cells, thereby absorbing the impact energy. In practice, Roho cushions provide far more stability than might be expected, because rapid destabilizing movements are damped by the cushion due to air flow resistance between the cells.

WEIGHT OF THE CUSHIONS

Hheavy cushions are of particular concern to users with limited upper limb strength, those who transfer independently from chair to car, and athletes who require minimal wheelchair weight for maximum performance. Gel or fluid cushions are usually heaviest, weighing in some cases over 20

pounds (9 kg). **Table 1** is derived in part from Jay (21) and lists the weights of some commercial cushions that weigh more than 3 pounds.

FRICITIONAL PROPERTIES

Fricitional properties are particularly important during transfers, as the user can easily fall if the cushion slips away. Yet, moderately low top surface friction is helpful during transfers, for users whose upper limbs are weak. One solution to this problem is to anchor the cushion with ties or Velcro. Although ties are useful in maintaining the position of the cushion during sitting, they are difficult if not impossible for the user to install independently prior to the transfer. For clients who have to fold the

Table 1.
Weight of Selected Commercial Cushions*

Cushion Name	Description	Approx. Weight	
		lb	kg
Modultex	Sculptured foam	4.5	2
Vasiopara	Sculptured foam	6.0	2.8
	+ sheepskin	10.0	4.5
Reston Flotation	Solid gel	13.0	6
Spence Omega 5000	Solid gel	14.0	6
Aberdeen	Thixotropic gel	14.0	6
SML Comfort	Thixotropic gel	12.0	5
Carter's Carterflow	Gel-foam	6.0	3
Grosvenor Medical	Gel-foam	8.0	4
Knoche Silicone	Gel-foam	6.0	3
Jay reg. adult	Gel-foam	7.0	3.2
Seabird	Gel-foam	7.0	3
Hydromedica	Water-foam	20.0	9
Western Medical	Water-foam	18.0	8
Jobst Hydrofloat	Water-foam	25.0	11
Ardo	Water	18.0	7
Lycro	Water	10.0	5
Roho	Air	5.0	2
Portallife	Foam-air mechanical	12.0	5.5
Safe-Seat	Foam-air mechanical	12.0	5.5
Healing Environment	Alternating air pressure	11.0	5

*Derived from Jay P: *Choosing the Best Wheelchair Cushion*. Washington, D.C.: RESNA, 1984.

chair frequently, ties are not practicable and most wheelchair users do not use them even when they are supplied by the cushion manufacturer.

Mating strips of hook-and-loop fastener (e.g., Velcro) may be sewn to the underside of the cushion cover and attached to the sling seat. We have experienced difficulty achieving a reliable long-term bond between the fastener strip and the sling seat, and when they fail, an ugly residue is left that is difficult to remove.

Instead, we use three of the sling seat attachment screws on each side of the frame for holding the loop fastener strip to the frame. A secondary advantage of using hook-and-loop fasteners is that the orientation of the cushion (top-bottom/front-back) is automatically defined.

Jay (1984) suggests that friction can be increased between the cushion and sling seat by using anti-skid netting, as used with rugs. Often, however, friction alone is not sufficient to prevent the cushion from being knocked out of place during the transfer.

CUSHION THICKNESS

Whenever possible, the cushion and wheelchair should be prescribed at the same time in order that wheelchair dimensions accommodate the thickness of the cushion. It is important to recognize that the cushion will be compressed in use when determining the position of the user with respect to the seat and back. This compression is uneven because of the localized distribution of pressure owing to the weight and anatomy of the individual (22,31).

For users with critical requirements, the cushion should be seen as an extension of his/her gluteal padding and the wheelchair dimensions selected in accordance with the prescribed cushion. For those with less critical needs, compromises can be made in both cushion and chair specifications, when they are evaluated together. Correct sitting height is crucial for optimal performance in the wheelchair.

APPEARANCE

For many people, appearance is quite important and should not be overlooked. Strategic use of cover materials, colors, and designs can be employed to disguise the utilitarian appearance of the “core” of the cushion.

COST

It should be remembered by prescriber, user, and insurer that the cheapest cushion is not necessarily the most economical. Some cushions are less durable than others, and for most wheelchair users, long-term rather than crisis economics should be employed. Many clinicians have expressed great concern over the cost of some cushions, especially those designed specifically for users vulnerable to pressure sores. In most cases, these costs are fully justified when the complexities of manufacture, development and distribution costs, and the relatively small size of the market are considered. According to a study by Noble (29), the average number of inpatient days required to heal an ischial pressure sore is 74 days. With per diem rates in rehabilitation hospitals exceeding \$500, the expense of a correctly prescribed cushion can be easily justified in economic terms alone, since it is likely to significantly reduce the risk of tissue breakdown.

DURABILITY AND NEED FOR USER MAINTENANCE

Materials used in the construction of wheelchair cushions vary greatly in their durability and longevity, and some cushion types require user maintenance.

All foam cushions deteriorate with time, even when they are not used. This is caused by increased brittleness of the polymer matrix, leading to fractures in the foam and softening of the cushion. Nobel *et al.* (30), found that storage over a even few months caused changes in the properties of foam cushions.

Fatigue

Fatigue is a deterioration in the supportive properties of the cushion due to prolonged use, and is a function of the time in use and the magnitude and number of stresses. Most foam cushions do not tolerate tension (“pulling”) and shear (“tearing”) well. Certain cushion designs, particularly those incorporating cut-outs, can produce very high tension and shear in the foam matrix, requiring them to be replaced more often than simple slabs of foam.

Exposure to moisture also shortens the life of foam cushions. Viscoelastic (Temperfoam) cushions are particularly susceptible to moisture, fatigue, and tearing. Gels also age by developing hard or consolidated local regions. Sometimes these regions can be “kneaded” to break up the lumps and prolong the life of the cushion. Both prescriber and user should be alerted to deterioration in gels, as these hard regions can pose a risk to tissue integrity.

Maintenance

Some cushions require the user to actively monitor and service them. Roho and other air-filled cushions require that the amount of air in the cushion be at a specific level for that individual.

Alternating pressure (ripple) cushions incorporate a battery-powered air pump and valve manifold to control the inflation of different panels or regions of the cushion. Maintenance for these cushions centers on regularly charging the battery.

Cushions requiring maintenance to ensure proper function should be prescribed only when the user or caregiver is physically able and willing to do so.

THE COVER

The cover is an important component in the cushion system. Some of the contributions to the performance made by the cover have already been referred to: moisture build-up, frictional properties, and appearance. Mechanically, the cover can modify the stiffness of the cushion core due to the “hammock effect” (7,15,34). Unless the cover is stretchable, it will not follow the surface of the compressed cushion, causing

the cushion to be harder than without the cover and, in turn, producing higher localized pressures over bony areas.

Users who experience frequent incontinence require some waterproofing to protect the core of the cushion if it is an absorbent type (e.g., foam). Otherwise, frequent washing should be all that is required. (It should of course be noted that good medical programs to manage incontinence are far more preferable than waterproof covers.) Most users with only infrequent accidents may prefer to risk wetting their cushion than to using a vinyl type cover. Simple foam cushions can be rinsed and spun dry, although it should be remembered that this shortens their useful life.* Viscoelastic foams should not get wet because they are irreparably damaged by fluids. Jay (21) points out that one of the difficulties with waterproof, nonabsorbent covers is that should an accident occur, puddling of urine on the cover can be very embarrassing. One approach is to use an inner waterproof liner (e.g., plastic waste-bin line) wrapped around the core of the cushion which can then be covered with a stretchable water absorbent material.

Sheepskin covers are widely used and offer many advantages. They absorb moisture (thereby reducing wetness due to sweating), contain lanolin, are washable, and have intrinsic mechanical properties that offer support and help to reduce pressure localization and shear. Lanolin, when in direct contact with skin, provides additional protection from moisture and friction. The appearance of sheepskin is highly acceptable to most users and it can be dyed. Denne (9,10) undertook studies that describe in detail both the pressure-distributing properties of sheepskin and the changes that can occur following repeated washings.

Brushing or combing the fleece helps to prevent felting of the wool fibers. Jay (21) and Menec *et al.* (27) discuss in depth the benefits of sheepskin, compare natural and synthetic fleeces, and recommend methods for washing and caring for them.

*Editor's Note. Washing a foam cushion will severely damage the foam's integrity. A soiled foam cushion can be 'dry' wiped clean and then dusted with cornstarch or crushed mothballs, or a mixture of the two to remove dampness and odor.

FLAMMABILITY

In a noninstitutional setting, flammability standards for cushions and covers need be no more stringent than for ordinary furniture and clothing, unless the user is confused, or has severe disabilities and is unable to get out of the chair unassisted. The greatest dangers arise in institutions where large numbers of cushions and mattresses can present a very serious fire hazard. When burned, plastic foams produce extremely poisonous gases that may incapacitate even more rapidly than the fire they support.

Smoking presents the greatest fire hazard to foam cushions in the home. Some covers can form an effective barrier between a dropped cigarette and the cushion, but may lose their fire retardant properties with frequent washing.

Roho, air-filled, and fluid-filled cushions are more resistant to burning. Plastic foams that have been treated with a fire retardant can be obtained. "Scott Foams" produce a foam called "Pyrell" that is particularly resistant to burning.

B. EVALUATING THE CLIENT

Before attempting to fit a cushion, it is important to identify the needs of the prospective user. A simple evaluation form may be helpful, ensuring that key points are covered and the goals for the user (and cushion) are understood and documented. Techniques for achieving these goals come with experience, but we hope with the help of expert system computer programs such as CUSHFIT (13,20), that we can make the process less specialized and more systematic in the future.

Many of the most difficult problems faced by wheelchair prescribers are associated with attempts to prevent pressure sores. When evaluating users vulnerable to pressure sores, it is important to determine whether:

- 1) sensation is total, partial, or absent,
- 2) any clinical conditions exist, placing them at higher than normal risk,
- 3) they regularly relieve tissue stresses by movement,
- 4) they spend prolonged periods of time sitting in their chair,

- 5) they produce unacceptably high localized stresses over bony prominences,
- 6) they are subject to heat and moisture accumulation due to exertion, environmental temperatures, and/or reflex sweating,
- 7) they have a good sitting posture,
- 8) they have good trunk stability,
- 9) an adverse skin condition exists.

Our approach to cushion fitting divides these factors into two groups. Type I are those that can be modified by a cushion/seating system, and Type II, those that are intrinsic to the user and place him/her at greater risk for breakdown.

Type I factors include:

- 1) highly localized stresses
- 2) heat accumulation
- 3) moisture accumulation
- 4) poor sitting posture and positioning
- 5) poor trunk stability.

Type II factors include:

- 1) degree of sensation
- 2) regular relief of stresses by movement.
(Note: some cushions accomplish weight shifting by alternating air pressure in local regions of the cushion.)

Establishing Maximum Allowable Interface Pressures

Reswick and Rogers (32) developed guidelines for maximum acceptable pressures at the skin/cushion interface, associated with a range of time intervals for which the pressure is applied (Figure 7). A number of important assumptions underlie these guidelines and should be seriously considered when implementing them clinically:

- 1) Their guidelines are intended for use with spinal cord injured outpatients.
- 2) They are intended to be used by associating the total sitting time with a maximum pressure over ischial tuberositates. It is assumed that the client performs push-ups, etc., with a frequency typical of the average spinal cord injured wheelchair user. This average frequency is not indicated nor is a correction factor given for other frequencies.
- 3) Some users may be at a higher risk for breakdown than others due to clinical factors (such as diabetes, presence of scar tissue

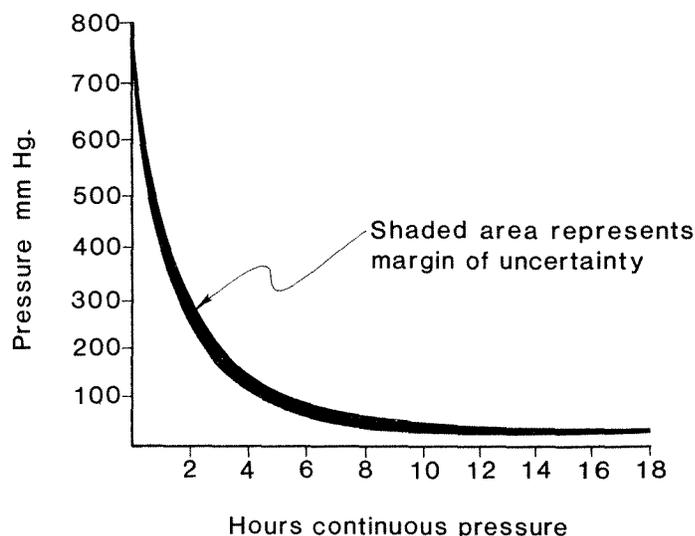


Figure 7.
Acceptable pressure/time interval guideline: Reswick and Rogers (1976).

or persistent skin redness, recent spinal cord injury) and reducing the maximum recommended pressure may be indicated.

- 4) Differences in the tolerance of tissues overlying different bony prominences (e.g., coccyx is much less tolerant than ischial tuberositates) are not reflected in the guidelines.
- 5) Presence of other stresses—particularly shear (coccygeal sitters) or repetitive loading (very active user)—should be accommodated by reducing the maximum recommended pressure.
- 6) Users with a tendency for self-neglect, taking physical risks, or whose family, social, or career commitments are unusually demanding, may tend to ignore or delay responding to precursors or actual breakdown. They require a recommended pressure-time guideline which pulls them back further from the threshold conditions for breakdown. This can be accomplished by taking rests from sitting during the day, by really performing push-ups, by reducing interface pressure—or preferably all three.

For many years, there has been a debate in the literature concerning maximum allowable pressures [see for example: Kosiak (24); Cochran and Slater (8); Edberg *et al.* (11); Reswick and Rogers (32);

Agris and Spira (1); Graebe (18); Noble (29)]. Discussion has centered on linking maximum allowable interface pressures with physiological parameters such as capillary perfusion pressure. These arguments are fraught with difficulty. For example, there is a large pressure drop across a capillary ranging from 30+ mmHg on the arteriole side to nearly zero on the venule side. Presumably, if sufficient pressure is applied to close off the outlet (venule) side of the capillary, no blood will flow.

I believe that interface pressure is only a relative indicator of the stresses and deformations occurring deep in the tissue, and that we should not attempt to link absolute values of interface pressure to physiological processes. Reswick and Rogers (32) contribute positively to the clinical use of pressure measurement, by at least emphasizing that in all probability, there is no one maximum allowable pressure to suit all individuals. They also expand the clinical guidelines to include a second variable—time.

At Helen Hayes Hospital we have expanded this concept to include other factors, and have established a simple scoring system that provides a maximum allowable pressure for each bony area at risk (**Table 2**). The basis for our scoring system is purely pragmatic, based on extensive experience with large numbers of spinal cord injured individuals. Part of our current research is designed to form, in collaboration with five other centers, a large database that will determine how effective this scoring system is, and whether additional factors need to be included.

Sitting Posture and Positioning

Scoliosis and pelvic obliquity cause uneven pressure distribution over the ischial tuberosities and greater trochanters, while rotation of the pelvis will result in excessive sacrococcygeal pressure. Methods for controlling these problems are discussed in depth by Zacharkow (37).

Wheelchair adjustments are critical during evaluation for the cushion, if the optimal posture and positioning of the user are to be preserved. If special supports are required, they should be in place during the evaluation. The use of an adjustable evaluation wheelchair, such as that described by Shapcott *et al.* (33), may prove to be helpful in optimizing concurrent cushion and wheelchair prescription.

Armrests and footrests can affect cushion performance dramatically. Support for the arms can reduce ischial pressures 25-35 percent (4). Footrests should be set, if possible, so that the thighs are horizontal and not bearing their own weight. If the footrests are too high, they transfer much of the weight of the thighs to the ischial tuberosities. If they are too low, they can promote sacrococcygeal sitting.

Bush (6) and Brattgard and Severinson (4) have also demonstrated marked reductions in ischial pressure (up to 25 percent) by reclining the backrest angle. Zacharkow (37) suggests that a seat angle of 10 degrees and backrest angle of 15 degrees are good average values to assure good posture, stability, comfort, and function. Increasing the seat angle excessively can transfer thigh weight to the ITs, and increasing backrest angle can produce greater shear stresses.

Table 2.
Recommended Maximum Acceptable Pressure

Level of risk	Ischial Tuberosities	Trochanters	Sacrum	Coccyx
High—no sensation; history of sores at site of measurement	40	60	< 20	< 20
Moderate—no sensation; no history of tissue breakdown	60	80	40	40
Low—partial or full sensation; no history of tissue breakdown	80	80	40	40

Note—These maximum recommended pressures assume a normal clinical status, push-ups performed every 15 minutes and no other factors that would increase the risk of breakdown. Prolonged sitting (>10 hrs) and infrequent pressure relief are weighted by reducing each of the maximum allowable pressures by 10 mmHg per factor. If risk is already high, then sitting time and/or pressure relief frequency *must* be brought to normal levels.

Sensation

In routine clinical evaluations, we normally rely upon the client's description of residual sensation.

Pressure Relief by Movement and Total Sitting Time

Pressure relief by movement and total sitting time are factors at the technological threshold of being directly monitored for routine evaluation. Fisher and Patterson (16), Merbitz *et al.* (28), and Burn *et al.* (5) are developing portable devices that will provide information about pressure relief and total sitting behavior. Merbitz *et al.* (28) and Fisher and Patterson (16) have collected sequential data in the hospital environment for up to 1 month. Burn *et al.* (5) now have a device capable of measuring pressure relief behavior and habitual sitting asymmetry, for more than a month in the home/workplace, without the need for battery recharging or data downloading. Until these systems complete preliminary development and clinical evaluation, we must rely upon the reports of the user.

Adverse Skin Condition

Adverse skin condition is monitored by direct observation. Intense activity continues in an attempt to identify methods for detecting early signs of tissue breakdown. These on-going studies involve measurements of: skin pO_2 , laser Doppler assessment of skin blood flow; ultrasonic properties of skin; and local temperature using thermography or liquid crystal film. In the meantime, the following scale is used for classifying skin condition associated with the development of pressure sores (3):

- Class 1: skin discoloration
- Class 2: superficial pressure sore
- Class 3: destruction of skin—no cavity
- Class 4: destruction of skin—cavity.

We also recommend that the presence of scarring be recorded. An instant photograph of problematic skin conditions kept in the medical record, is valuable for the review of progress and planning.

C. SOME USEFUL TECHNIQUES FOR MATCHING CUSHION WITH CLIENT

Devices for Measuring Interface Pressure

Devices for measuring the pressure (normal

stress) between the skin and the cushion can be used to locate regions of localized pressure, and indicate how they are distributed by a cushion. It is important to remember, however, that pressure measurements made at the skin's surface are thought to be much lower than those deep in the tissues, where pressure sores initially develop. For users with sensation, subjective feedback of comfort is far more desirable than rigid adherence to a method involving maximum interface pressure.

Pressure sensors fall into the following categories:

- 1) discrete sensor, single measurement
- 2) multiple sensor, single measurement
- 3) discrete sensor, continuous measurement
- 4) multiple sensor, continuous measurement.

Until recently, sensor types (1) and (2) have been most widely used in cushion-fitting clinics. Two discrete sensor systems providing single or snapshot type measurements are currently available commercially in the USA:

Type (1) Skin Pressure Evaluator (SPE) (Figure 8)

Camp International Inc.
PO Box 89
Jackson, MI 49204
1-800-492-1088

[A fuller technical description of this device is given by Reswick and Rogers (32).]

One multiple sensor snapshot or single reading device is commercially available:

Type (2) TIRR Pressure Evaluator Pad (PEP) (Figure 9)

Tee Kay-Applied Technologies
11915 Meadowtrail Lane
Stafford, TX 77477
(713) 495-6838

[A fuller technical description of this device is given by Krouskop *et al.* (25).]

One suitable continuous reading device is commercially available:

Type (3 and 4) Oxford Pressure Monitor (OPM)

Camp International Inc.
PO Box 89
Jackson, MI 49204
1-800-492-1088

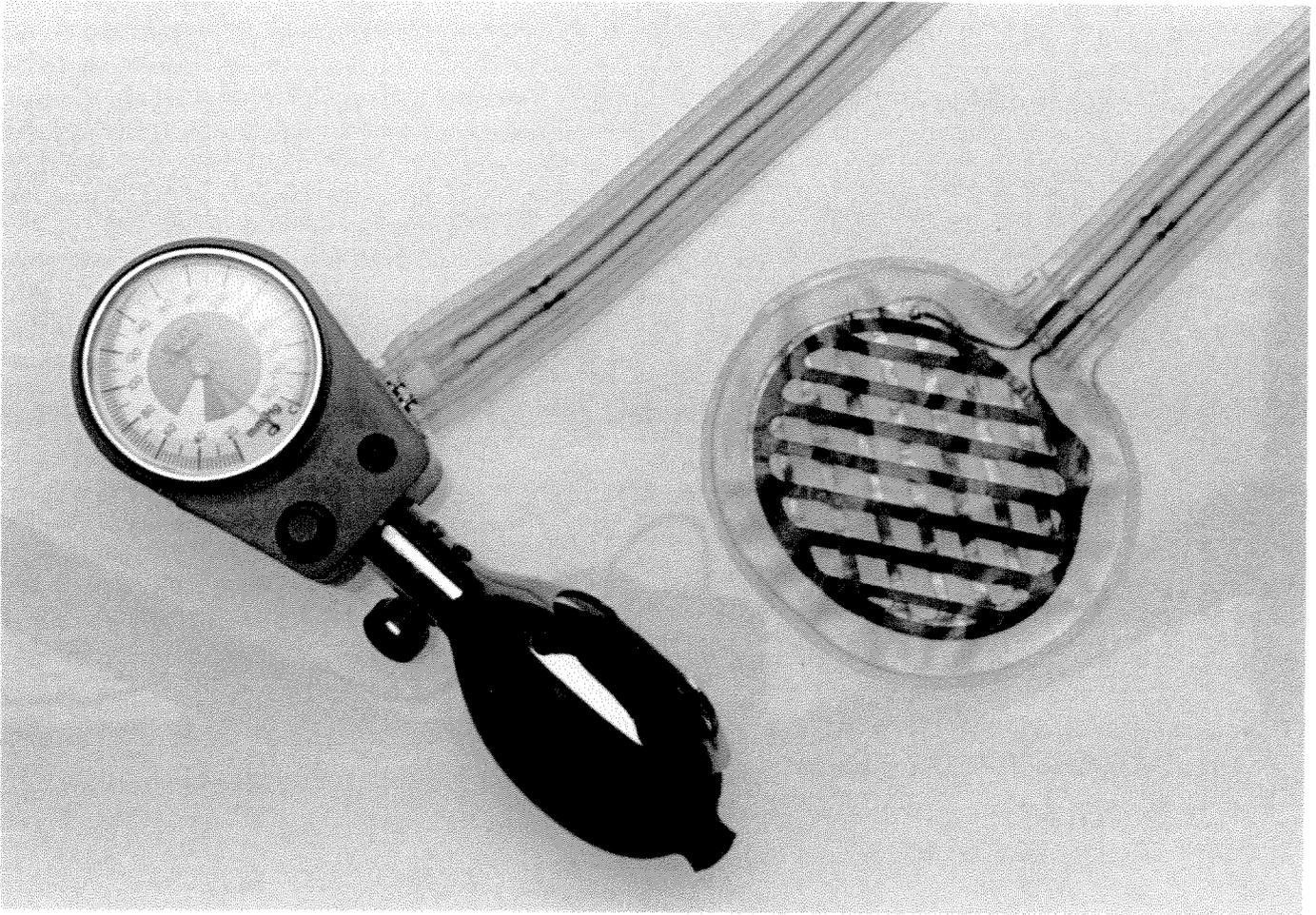


Figure 8.
Skin Pressure Evaluator.

Appropriate configuring of the OPM can provide single sensor continuous measurement (type 3) or multiple sensor (type 4) capability.

The SPE consists of a 4-inch diameter polyethylene sack lined on its inner surface with an electrically conductive grid. It is inflated manually using a sphygmomanometer which also indicates the pressure inside the sack. The grid functions as a switch which controls a small light on the sphygmomanometer. When the pressure inside the sack exceeds the pressure applied by the body, the two grids are separated and the light is extinguished. As air pressure is reduced using the bleed screw on the sphygmomanometer, a critical point is reached where the light is suddenly illuminated. Bleeding of air from the sack is stopped by the operator and the air pressure measured indicating the maximum

(peak) pressure over the bony area. In fact, the air sack does provide some support for the tissues surrounding the center of the pressure distribution. This results in readings that are somewhat lower than the true peak pressure. The size of this error depends upon how localized the peak pressure is (14). In effect, this means that unacceptably high pressures are even higher than measured, whereas "acceptable" pressures may be marginally greater than indicated.

The PEP pressure monitor consists of an array of 144 discrete pressure sensors approximately 1.25 inches between centers. A similar principle of operation is used in this device in that the sensor matrix is formed from a flexible sheet of plastic, each divided from the next using a welded seam. All the air cells are, however, interconnected and are inflated from a single air pressure source. Each cell



Figure 9.
TIRR Pressure Evaluation Pad.

is coated with a ribbon of electrically conductive paint that functions in a similar way to the metal grid of the SPE. The commercially produced system is designed to provide a readout using an array of lights. Several research centers have connected the matrix of sensors to a personal computer and have developed software that can plot pressure contours directly using a printer. The matrix is inflated to 80-90 mm Hg at which point it is assumed that the lights on the display array will be extinguished. If the local pressures are higher than the maximum inflation pressure, cells that are "on" are recorded as ">90 mm Hg." The pressure in the matrix is then reduced using a bleed screw in increments of 5-10 mm Hg and the pattern of lights are recorded at each increment. This system, therefore, provides a direct contour map of the interface pressures. Its disadvantages include relatively high cost, a maxi-

imum pressure range limited to about 90 mm Hg, and only moderate durability of the sensor matrix (which is subject to replacements due to fatigue in the conductive paint).

The OPM consists of a 3 x 4 matrix of sensors, again incorporating air cells sealed into a flexible plastic sheet. This design does not, however, utilize electrical contacts and the sensors are therefore more robust than the SPE or PEP. The control unit that provides the inflation source for the cells and for a readout display automatically scans the sensors, rapidly reading the pressure at each sensor every 2 to 3 seconds. The device employs the following principle. When a cell is collapsed due to the pressure applied by the body, the flow rate of air to the cell is very small. Suddenly, when the air pressure in the cell is equal to the applied pressure, the cell inflates and the flow rate of air increases

rapidly. By monitoring both the inflation pressure and the flow rate of air to the cell during the inflation cycle, a "knee" in the pressure versus the flow rate curve can be detected and the pressure displayed. The output can be displayed using a serial interface to a personal computer or by using the small printer provided to produce a hard copy record.

Measuring Interface Pressure

The number and location of the sites for pressure measurement should be guided by clinical judgment. Most often, pressures are measured under the ischia, trochanters, and coccyx, and frequently, one or two sites are of particular concern. To save time, usually only the pressure at problem areas is measured until a cushion has been identified that provides adequate readings at these sites. We then check the remaining areas of interest, which will invariably be satisfactory. Two exceptions exist, if:

1) scoliosis is present. Relieving the high-pressure side may well overload the opposite side. Both should be measured throughout the evaluation.

2) the user is a coccygeal sitter. Relieving sacrococcygeal pressure by reducing posterior pelvic tilt can also result in a substantial increase in ischial pressure. The sacrococcygeal region and at least one IT should be monitored throughout the evaluation.

All sites clinically determined to be vulnerable to breakdown must be measured, and the results documented, prior to issuing the cushion.

The air cell may be inserted from either side of the wheelchair, or from behind. The transducers are located by palpation under bony prominences. It is often helpful to remove screws from the lower-back upholstery and bend it up. This is particularly helpful in checking the fit and pressures on cut-out cushions.

To measure pressure on each cushion:

1) ask or assist the user to lift his/her buttocks off the cushion;

2) palpate the bony prominence and place the pressure sensor pad under the center of this area; hold it in place as the user resumes a relaxed sitting position;

3) remove your hand without disrupting the placement of the pressure sensor pad (sometimes a

little talcum powder for your hands will make this a little easier);

4) check the user's posture;

5) close the valve and inflate the sensor pad until the indicator lamp goes off; slowly release the air and record the pressure reading at the moment the lights go on;

6) repeat the process of palpation, placement and measurement.

Usually, two readings suffice for each site. If successive readings are significantly different (>5 mm Hg), check placement and the user's posture, and take readings until consistent values are obtained. Occasionally, the indicator lamp may fail to go out, even if inflated to high pressures, because of a fold in the sensor pad or possibly because it has a damaged cell. If this happens, reposition the sensor pad and repeat the measurement. If this does not resolve the problem after two or three attempts, inspect the metal grid of the cell for damage (delamination). When using viscoelastic foams (Temperfoams) wait 5-10 minutes after placement of the air cell before taking your set of readings to ensure that the material has conformed to the shape of the client.

When evaluating cushions of different thicknesses, it is important to remember that the footplates, armrests, and/or other wheelchair components must be readjusted for each cushion.

Location of Bony Prominences

Location of bony prominences should be determined when fitting cushions which have been, or will be, custom-formed to provide local relief of bony areas (cut-out cushions; ideally commercially preformed contoured cushions such as the Vasiopara and the Jay, **Figure 10**). It is wise to accurately measure the location relative to the wheelchair, and the separation of the two ITs, and possibly the coccyx.

A number of techniques can be employed:

Palpation. With the user side-lying, hips and knees flexed to 90 degrees, with a 90-degree thigh to trunk angle, the ischial tuberosities are palpated. The distance is measured from the most prominent part of one tuberosity to the corresponding point on the other. This technique is extremely simple and requires no equipment, but unlike the methods

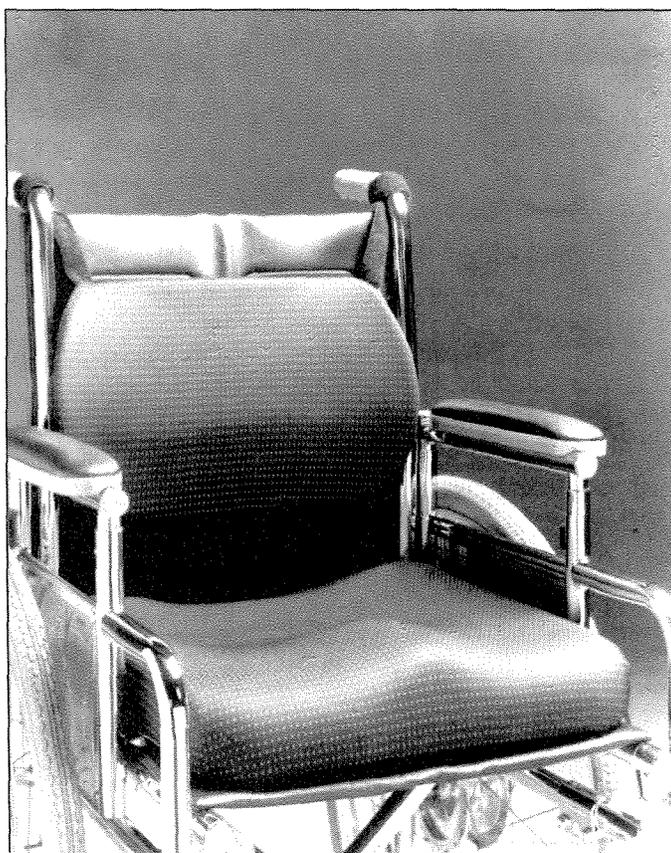


Figure 10.
Jay "Combi Posture Seat."

described below it does not provide an indication of the location of the ITs relative to the seat and back of the wheelchair, and hence their location on the cushion to be prescribed.

Carbonized paper. Carbonized paper can be used to produce an imprint of bony areas. One of the difficulties with this technique can be the smearing of the imprint in the process of achieving the normal sitting position.

A simple way to reduce this problem involves constructing an air pillow from vinyl or other heat sealable plastic and fitting it with a suitable inflation tube and valve. A sheet of the carbonized paper (we use Shutrak gait analysis paper*) is placed on a firm surface in the chair (seatboard plus 1 inch foam

works well), and the air pillow is then placed on top and inflated sufficiently to support the user's weight without bottoming out. Thus, no localized pressure is transmitted to the carbonized paper. It is desirable to make the impression with the user sitting at the normal sitting height in the chair, with armrests and footrests adjusted appropriately.

With the user correctly positioned, the air is released from the pillow and an imprint is made. The pillow is then reinflated using a hand-pump and the person carefully transferred. The measurements of inter-IT distance and location of bony areas relative to the chair can be made, and if required, a hard copy kept for the record.

Bead-bag. This technique is used to make temporary "casts" of users for molding custom postural seating systems. It can also be used to obtain an impression of the gluteal region. The areas of deepest impression correspond to the bony prominences. This technique works best with individuals who are not "well-padded."

A thin, flexible sack preferably made from latex, is filled with enough glass or Styrofoam beads to produce a layer 1-inch thick when the bag is flattened. The user is asked to sit on the sack, again on a firm surface, and the air is then evacuated using a vacuum pump. This leaves a hard shell-like impression of the gluteal region, and the deep indentations of the ITs can be identified.

Barograph. This device is described in full by Mayo-Smith and Cochran (26). A Plexiglas plate, which is illuminated from the side with fluorescent lamps, supports a rubber sheet which has been molded to form conical projections on one surface. When viewed from below, cones which have been compressed reflect more brightly than the uncompressed cones. When sat upon, areas of highest pressure cause greatest compression of the cones, and the result is an image with a bright region corresponding to the bony areas. It produces a dynamic image indicating the effects caused by changes in posture, reduced pelvic obliquity, rotation, and other factors.

TIRR PEP Pressure evaluator. One of the attributes of this sensor is its capacity to produce a direct pressure map of the gluteal region. Bony areas can therefore be identified easily as areas of peak pressure, and their location measured.

*Notecare Inc., 2435 Professional Dr., Suite C, Santa Rosa, CA 95401.

Removing Sling-Seat Sag

We frequently encounter wheelchairs with excessive sling seat sag, and often, it is severe enough to justify replacing the seat canvas. The following techniques are helpful in eliminating the consequences of sag: knee adduction, high trochanteric pressures, reduced stability, and discomfort.

One technique that has been used for many years is to place a plywood board across the seat frame or use drop-hooks to suspend it from the frame. Thin boards can also be placed in the base of the cushion, but they have to be manageable and they tend to flex. These methods are effective, but they can make independent transfers more difficult when the chair has to be folded. Also, bases that are screwed to the frame of the chair tend to affect the ride. Wheelchairs need to flex when traveling over uneven terrain because, unlike automobiles, they are not routinely fitted with a suspension system.

Our solution to this problem has been to form a base for the cushion from Plastazote or Ethafoam. The base is cut to a convex shape on its lower surface, so that it fills the concave space generated by the sling-seat. The base can be attached to the cushion and placed within the cover. As an integral part of the cushion, it is lightweight and doesn't interfere with transferring.*

The Cut-Out Cushion

The principle of load distribution has already been discussed (**Figure 2**). Cut-out cushions help by redistributing the body weight normally borne by the ITs, more equally with the posterior aspect of the greater trochanters. The concept was first introduced by Reswick and Rogers (32) and has been discussed in depth by Ferguson-Pell *et al.* (12,13), Key and Manley (23), and Zacharkow (38).

A rectangular region from a slab of firm polyurethane foam (density 3.25–3.75 pounds/cubic feet; indentation load deflection (ILD) (25 percent) 60–80 pounds) is removed with an electric carving knife. The size of the cut-out is determined precisely for each individual, based on the measured location and separation of the ITs. A margin of 1.25 inches lateral and 1.5 inches anterior to the center of each IT is allowed, making the cut-out slightly larger in width and depth than the inter-ischial and seatback-

to-ischia distances. Persons with a natural tendency to sit obliquely, or those who sit slightly off-center, should be accommodated with a correspondingly shaped cut-out, if correction is not indicated. The depth of the cut-out should not exceed half the thickness of the cushion. Cushions should not be less than 3 inches thick and at least 4 inches is preferred. To reduce shear at the margin of the cut-out, a chamfer 1 inch deep at 30 degrees can be cut along the periphery.

Variations of this design include using low density foam fillers and cut-outs on the under-surface of the foam instead of the top. Undercut-outs can also be filled with low density foam. We recommend that an Ethafoam base be used with all cut-out cushions so that the cushion does not "fold" when placed in a sagging sling seat. The Ethafoam base itself could be cut, in addition to, or instead of the cushion, allowing for more foam between the buttocks and base while benefiting from the modified shape, without gaining additional total thickness.

This approach requires experience to use effectively, but provides fine control of the relative loading of the trochanters and ITs. Cut-outs can also be used to provide sacrococcygeal sitters without independently controlling anterior pelvic rotation. Zacharkow (37) suggests that this can often be achieved using a lumbar pad and a 95-degree thigh-to-trunk angle.

When using cut-out cushions it should be noted that: 1) a flexible cover should always be used with cut-out cushions; 2) a firm base is always required to prevent inwards folding of cut-out dimensions due to sling seat sag; 3) the overall dimensions of the cushion should be cut precisely, to ensure that the cushion is located securely in the same place each time. Velcro attachment as described above is recommended; 4) dimensions of the cut-out must be measured for each individual; 5) the durability of cut-out cushions is not as good as plain foam cushions. They should be replaced on the average of every 6 months. Thus, this type of cushion should only be prescribed when the means for reliable follow-up are present, and the user can be relied upon to meet scheduled appointments; and, 6) both trochanteric and ischial pressures must always be measured when evaluating cut-out cushions, because it is crucial that goal pressures for both sites are met. Where possible, an accepted pressure a little

*Alimed, 297 Hyde St., Dedham, MA 02026 (800-966-4262), supplies these bases, preformed for easy use.

lower than the goal pressure should be attempted, in order to allow for changes in the foam in the first few weeks of use.

Despite these constraints, we find that cut-out cushions are extremely useful for users with pronounced tissue wasting in the gluteal region, when more straightforward cushion systems fail to reduce interface pressures sufficiently, or are not applicable for other reasons.

The Modular Cushion

The modular cushion is designed to assist those at low-risk for pressure sores whose needs cannot be met by the simple foam cushion. The modular cushion concept (15) consists of up to four layers of component materials. Each layer is selected to contribute to the overall properties of the cushion.

A wide range of commercially produced materials is available. The system makes use of combinations of three classes of materials ordinarily used alone: foams, temperfoams, and gels. The construction of a typical cushion is described below and illustrated in **Figure 11**.

COVER:

Purpose: to provide a cover that is adequate for carrying, as well as contacting body surface.

Support Segment (bottom, sides, back): a smooth, strong, light, flexible, easily cleaned material that is adequate to support and transport the cushion.

Body Contact Segment: a durable, porous, two-way stretch, absorbent, easily cleaned, cotton/polyester jersey-type fabric.

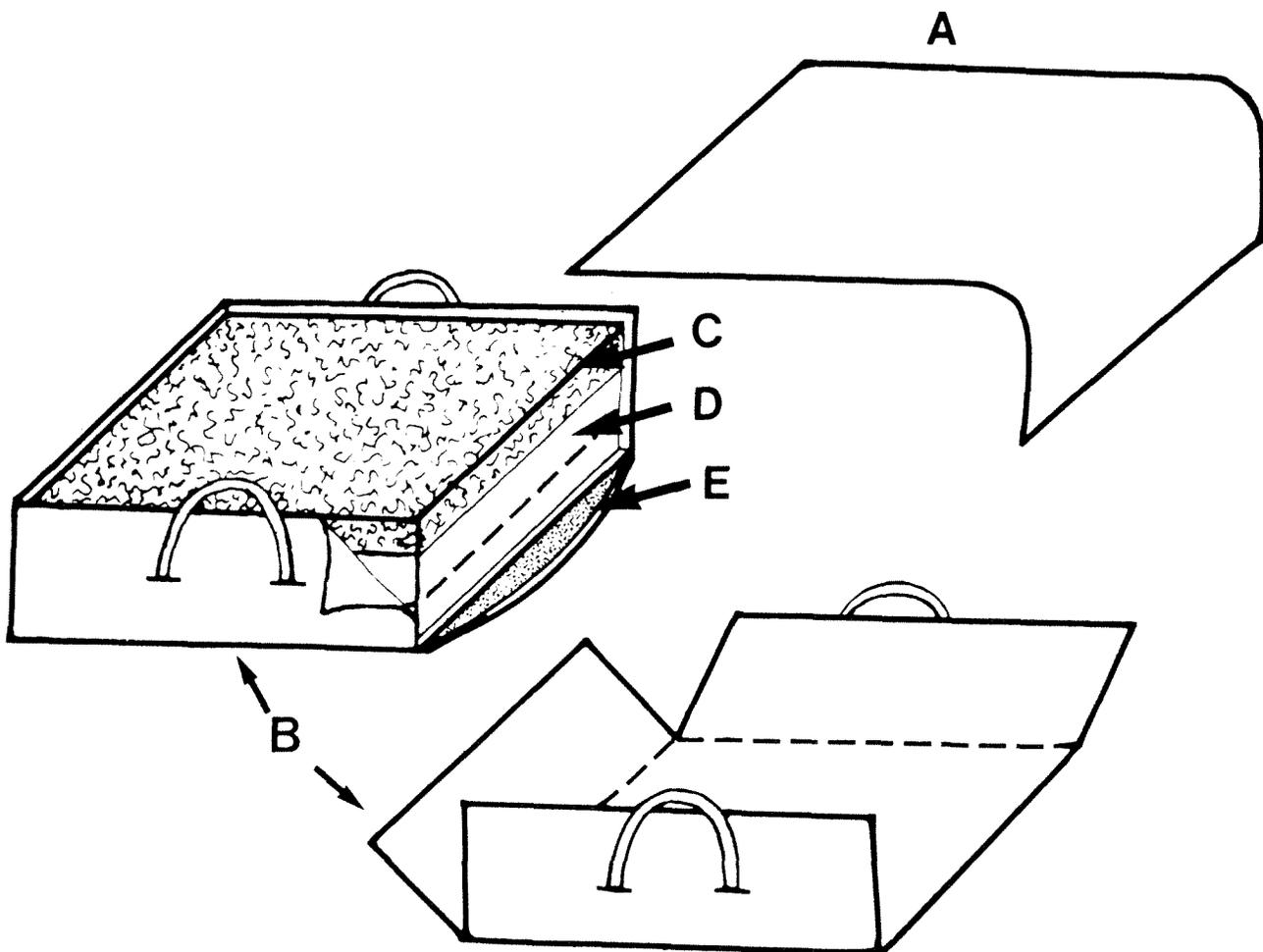


Figure 11. Schematic of a modular cushion showing: A) body contact segment of cover; B) support segment of cover; C) top layer of support system; D) middle and bottom layers; and, E) convex base. (Reprinted from Ferguson-Pell *et al.*, *J Rehabil Res Dev* 23(3):65, 1986.)

TOP LAYER:

Purpose: to encourage air circulation and reduce sitting pressure. (This layer may be omitted when heat dissipaters such as gels are used for the middle layer.) A soft open-cell or reticulated foam; thickness 0.5–1.0 inches is recommended. If pressure relief is a critical factor, a denser, easily washable or disposable material may be selected instead. (Note: if necessary for the protection from fluids, the underlying middle and bottom layers may be enclosed in a thin, loose, waterproof plastic bag.)

MIDDLE LAYER:

Purpose: to reduce pressure and shear forces, and control heat dissipation. The qualities of this layer may be selected to suit the most urgent needs of the user. Various medium or high density foams and gel components; 1.0–2.0 inches thick can be used.

BOTTOM LAYER:

Purpose: similar to middle layer, but this layer is selected primarily to augment the favorable qualities of the middle layer, and offset any unfavorable qualities. Viscoelastic foams may be used to improve conformance and reduce pressures; firm foams may be used to counter a tendency to bottom out.

BASE:

An Ethafoam base, as described above, is required to reduce the effects of sling seat sag.

D. WHEELCHAIR CUSHION FITTING CLINICS

Reswick and Rogers (32) established the first wheelchair cushion fitting clinic at Rancho Los Amigos Hospital. Their clinic focused primarily on the needs of spinal cord injured patients at risk for developing pressure sores. Through this clinic evolved the design and application of the SPE pressure evaluator and the cut-out cushion.

The clinic was established, not only to prescribe wheelchair cushions but also to provide a focus for developing and reinforcing self-help methods of pressure sore prevention, to monitor skin condition on a regular basis, and to provide ongoing education.

Ferguson-Pell *et al.* (12), Key and Manley (23), Noble (29), Krouskop *et al.* (25), and others developed similar clinics around the world, with many local variations in techniques and materials. Each clinic claims marked reductions in pressure sore incidence. Ferguson-Pell *et al.* (1985a), monitoring a spinal cord injured population, noted a reduction in admission for treatment of ischial pressure sores from 12 percent to 5 percent following adoption of the cushion fitting clinic concept. Similar successes were reported at the other clinics.

The following components are required to establish an effective cushion fitting clinic:

Human resources. Most clinics operate within a team approach framework. Although details of fitting the cushion may have to be resolved by one or two cushion-fitting specialists, it is important that the rehabilitation team be involved in setting goals. In general, physical and occupational therapists have the primary skills and training required to be responsible for the clinic, and to work closely with the physician.

It is important to assign one or two therapists to be responsible for the clinic, and to develop an experience-base which will be vital in solving more difficult cases. This leaves the clinic vulnerable, because should key personnel leave, the skill-base is lost and the clinic will take several steps backwards while the new staff develops experience. These are the dangers of specialization. But the alternative—rotating responsibility for the clinic—can lead to communication problems, lack of continuity for the client, and a reduced skill-base. CUSHFIT (see following section in this chapter) has been designed to reduce the problems of specialization. It is recommended that the clinic be open at regular times each week (half-day blocks will be needed) and that new evaluations, which take longer, should be separated from follow-ups.

Material resources. Instruments for measuring interface pressure and the location of the ITs will be required. In addition, an ample supply of various densities of foam and frequently prescribed commercial cushions should be available. If the cushion prescribed is commercially produced, an order should be placed in the usual way, keeping the evaluation stock intact. Custom-made cushions can often be made on the spot and fitted with one of a number of standard covers. Temporary foam cushions may also be supplied while waiting for the

commercial cushion to be delivered or a special fabrication to be completed.

Documentation. It is crucial that detailed records be kept for each evaluation. Results from previous evaluations can save many hours of follow-up by avoiding duplication of effort. Documentation should include: 1) summarizing the clinical evaluation of the user; 2) setting goals that are acceptable to the team and the user; 3) recording the observations and measurements made during the evaluation; and, 4) reporting use protocols, follow-up frequency, precautions, etc.

Scheduling. The clinic should have the means to reliably follow clients on a long-term basis. This may have to be a rather paternalistic process, but necessary since clients may be using cushions which deteriorate rapidly. Their awareness of the need to follow-up must be reinforced continuously, backed up by telephone calls and reminder cards.

E. CUSHFIT

CUSHFIT is an expert system computer program that has been developed by the Orthopaedic Engineering and Research Center of the Helen Hayes Hospital (13,20). Recognizing the problems of therapist specialization discussed above, CUSHFIT has been designed to guide the less specialized therapist through the fitting procedure in an effective and efficient manner.

The program operates on the IBM PC and XT personal computers equipped with 256K resident memory, two disk drives, color graphics display, and a printer.

Initially, basic clinical and administrative information is collected. Observations of skin status at each bony site, and other factors, are used to weigh the prospective user's level of risk for developing pressure sores. Maximum acceptable pressures (goal pressures) are then established, as described in **Table 2**. At all times, the therapist has full control of the program and is able to interactively modify both the goals recommended by the program, and cushions that it specifies.

Pressure readings are obtained on two reference cushions (medium and firm foam) and are used by the program to establish a sequence of cushions, commercial and custom, to be evaluated. The sequence has been designed to reach a satisfactory

solution for a minimum number of different cushions evaluated (critical path approach).

CUSHFIT offers a number of benefits:

- 1) it automatically documents, stores on disk, and prints in approved medical format all observations made during the evaluation;
- 2) it ensures that consistent goals and protocols are maintained in the clinic, thereby providing quality assurance;
- 3) automatically develops a database for the clinic which may be used for administrative and research purposes;
- 4) reduces the need for specialist therapists to operate the clinic and reduces the impact of staff turnover;
- 5) incorporates a scheduling program to automatically keep track of clients by generating form letters and updating central ambulatory care records.

CONCLUSION

When selecting a seat cushion, basic physical and clinical principles should be applied to ensure that the best choice is made. Unless there is no alternative, the seat cushion should always be prescribed simultaneously with the wheelchair. This ensures that we do not have to compromise our goals unilaterally (to either the cushion or chair, whichever happens to be prescribed last) and that dimensional adjustments can be made to accommodate ergonomic and functional needs.

It should be recognized that seat cushion selection is not a simple process—no single cushion, at present, meets the needs of all users. The number of parameters which have to be controlled is considerable, and unless we adopt a highly structured approach to cushion selection, one of two frequently encountered problems can occur. We could limit our choice of candidate cushions to a small, manageable number with consequent compromises in the final result. Alternatively, we could try to juggle all the factors at once, and become so confused by options that the “best fit” would be made by chance rather than design.

This article has discussed ways of keeping our options open while maintaining a professionally based strategy for selection. Pivotal to the process is an understanding of the properties of cushions and

the principles of correct seating and positioning. Success has been catalyzed by the availability and correct use of measurement tools that provide both quantitative and qualitative feedback of how the client and the cushion interact.

ACKNOWLEDGMENT

Drawings for **Figures 1, 2, 4, 5, 7**, were done by Samuel McFarland. Photographs for **Figures 3, 6, 8, 9**, and **10** are printed with permission of the manufacturers.

The author acknowledges that many aspects of the information in this article were developed from programs begun in 1970 by Dr. G.V.B. Cochran at the Helen Hayes Hospital and supported by the Veterans Administration and the Paralyzed Veterans of America.

REFERENCES

1. **Agris J, Spira M:** Pressure ulcers: Prevention and treatment. *Clin Symp* 31(5):2-8, 1979.
2. **Bader DL, Gwillim J, Newson TP, Harris D:** Pressure measurement at the patient support interface. In: *Biomechanical Measurement in Orthopaedic Practice*, Whittle M, Harris D (Eds.), 145-150. Oxford: Oxford University Press, 1985.
3. **Barbenel JC, Jordan MM, Nicol SM, Clark MO:** Incidence of pressure sores in Greater Glasgow Health Board Area. *Lancet* 2:548-550, 1983.
4. **Brattgard S-O, Severinsson K:** Investigations of pressure, temperature and humidity in the sitting area in a wheelchair. In *Biomechanics VI-B: International Series on Biomechanics*, Asmussen E, Jorgensen K (Eds.), 270-273. Baltimore: University Park Press, 1978.
5. **Burn TG, Ferguson-Pell MW, Hurwitz DE:** Pressure relief monitoring device. In *Proceedings of the 8th Annual Conference on Rehabilitation Technology* 5:42-44. Washington, DC: Association for the Advancement of Rehabilitation Technology, 1985.
6. **Bush CA:** Study of pressure on skin under ischial tuberosities and thighs during sitting. *Arch Phys Med Rehabil* 46:202-213, 1969.
7. **Chow WW, Juvinal RC, Cockrell JL:** Effects and characteristics of cushion covering membranes. In *Bed-sore Biomechanics*, Kenedi RM, Cowden JM, Scales JT (Eds.), 95-102. Baltimore: University Park Press, 1976.
8. **Cochran GVB, Slater G:** Experimental evaluation of wheelchair cushions: Report of a pilot study. *Bull Prosthet Res* BPR10-20:29-61, 1973.
9. **Denne WA:** An objective assessment of the sheepskin used for decubitus prophylaxes. *Rheum Rehabil* 18:23, 1979.
10. **Denne WA:** Fleece mechanics. *Care, Science and Practice* 2(4):14-15, 1983.
11. **Edberg LE, Cerny K, Stauffer ES:** Prevention and treatment of pressure sores. *Phys Ther* 53(3):246-252, 1973.
12. **Ferguson-Pell MW, Wilkie IC, Reswick JB, Barbenel JC:** Pressure sore prevention for the wheelchair-bound spinal cord injured patient. *Paraplegia* 18:42-51, 1983.
13. **Ferguson-Pell MW:** Establishing a pressure sore prevention service. In *Chronic Ulcers of the Skin*, Lee B (Ed.), 203-212. New York: McGraw-Hill, 1985a.
14. **Ferguson-Pell MW, Reddy NP, Stewart SFC, Palmieri V, Cochran GVB:** Measurement of physical parameters at the patient support interface. In *Biomechanical Measurement in Orthopaedic Practice*, Whittle M, Harris D (Eds.), 133-144. Oxford: Oxford University Press, 1985b.
15. **Ferguson-Pell MW, Cochran GVB, Palmieri V, Brunski JB:** Development of a modular wheelchair cushion for spinal cord injured persons. *J Rehabil Res Dev* 23(3):63-76, 1986.
16. **Fisher SV, Patterson R:** Long-term pressure recordings under the ischial tuberosities of tetraplegics. *Paraplegia* 21:99-106, 1983.
17. **Garber SL, Krouskop TA:** Body build and its relationship to pressure distribution in the seated wheelchair patient. *Arch Phys Med Rehabil* 63:17-20, 1982.
18. **Graebe RH:** Static forces-cushion. *Care, Science and Practice* 1(1):50-53, 1981.
19. **Hobson DA, Nwaobi OM:** The relationship between posture and ischial pressure for the high risk population. In *Proceedings of the 8th Annual Conference of Rehabilitation Technology* 5:338-340. Washington DC: Association for the Advancement of Rehabilitation Technology, 1985.
20. **Hurwitz DE, Ferguson-Pell MW, Burn TG, Cardi M:** An integrated approach to pressure sore prevention for the spinal cord injured. In *Proceedings of the 8th Annual Conference on Rehabilitation Technology* 5:142-144. Washington DC: Association for the Advancement of Rehabilitation Technology, 1985.
21. **Jay P:** Choosing the best wheelchair cushion. Distr. RESNA Publications Service, Suite 700, 1101 Connecticut Ave NW, Washington DC 20036, 1984.
22. **Kadaba MP, Ferguson-Pell MW, Palmieri VR, Cochran GVB:** Ultrasonic mapping of the buttock-cushion interface contour. *Arch Phys Med Rehabil* 65:467-469, 1984.
23. **Key AG, Manley MT:** Pressure redistribution in wheelchair cushion for paraplegics: Its application and evaluation. *Paraplegia* 16:403-412, 1978-79.
24. **Kosiak M:** Etiology and pathology of ischemic ulcers. *Arch Phys Med Rehabil* 40:62-69, 1959.
25. **Krouskop TA, Noble PC, Garber SL, Spencer WA:** The effectiveness of preventive management in reducing the occurrence of pressure sores. *J Rehabil Res Dev* 20(1):74-83, 1983.

26. **Mayo-Smith W, Cochran GVB:** Wheelchair cushion modifications: Device for locating high pressure regions. *Arch Phys Med Rehabil* 62:135-136, 1981.
27. **Menec JM, King MW, Leach SJ, Shannon EE:** Designing polyester fleece decubitus pads. In *Proceedings, 2nd International Conference on Rehabilitation Engineering*, Ottawa, 465-466, 1984.
28. **Merbitz CT, King RB, Bleiberg J:** Continuous direct recording of wheelchair pressure relief behavior. *Arch Phys Med Rehabil* 64(abstr), 1983.
29. **Noble PC:** The prevention of pressure sores in persons with spinal cord injuries. In *International Exchange of Information in Rehabilitation* New York: World Rehabilitation Fund Inc., 1981.
30. **Noble PC, Goode B, Krouskop TA, Crisp B:** Influence of environmental aging upon the loadbearing properties of polyurethane foam. *J Rehabil Res Dev* 22(3):31-38, 1984.
31. **Reger SI, Chung KC, Martin G, McLaurin CA:** Shape and pressure distribution on wheelchair cushions. In *Proceedings of the 8th Annual Conference on Rehabilitation Technology*, 5:341-343. Washington DC: Association for the Advancement of Rehabilitation Technology, 1985.
32. **Reswick JB, Rogers JE:** Experience at Rancho Los Amigos Hospital with devices and techniques to prevent pressure sores. In *Bedsore Biomechanics*, Kenedi RM, Cowden JM, Scales JT (Eds.), 301-310. Baltimore: University Park Press, 1976.
33. **Shapcott N, Heinrich C, Brubaker C, Ferguson-Pell, M:** A methodology to assist in the prescription of wheelchairs. In *Proceedings of the 9th Annual Conference on Rehabilitation Technology* 6:378-380. Washington DC: Association for the Advancement of Rehabilitation Technology, 1986.
34. **Small CF:** Beds. PhD diss., University of Strathclyde, Glasgow, Scotland, 1977.
35. **Stewart SFC, Palmieri V, Cochran GVB:** Wheelchair cushion effect on skin temperature, heat flux and relative humidity. *Arch Phys Med Rehabil* 61:229-232, 1980.
36. **Trefler E:** Seating for children with cerebral palsy: A resource manual. Washington DC, 1984.
37. **Zacharkow D:** Wheelchair Posture and Pressure Sores. Springfield, IL: CC Thomas, 1984.