Wheelchair Cushions: A Historical Review

(equipment, seating; pressure, evaluation; wheelchairs)

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An important objective of occupational therapy practice is to maximize functional potential in patients who have physical disabilities. Pressure sores are a major complication in the medical course of these individuals. Therefore, prevention, or at least the proper management, of these sores becomes an important focus for occupational therapists who treat the physically disabled patient. Occupational therapists often prescribe wheelchair cushions to relieve pressure and reduce the risk of ulceration. Unfortunately, occupational therapy literature offers few articles dealing with this significant problem. This paper presents a historical review of wheelchair cushions and details some of the physiological and clinical research efforts that are the basis of prescription practice today.

Pressure sores are a frequent and potentially life-threatening complication for the individual with a severe physical disability. The sores are a significant deterrent to patients' participation in the activities that help them resume independent and productive lives. Pressure sore prevention begins by having patients receive good nursing care during the acute phase of hospitalization. However, if sores do occur, numerous pressure relief devices for both the bed and the wheelchair have been developed and evaluated that reduce or eliminate the effects of pressure on the tissue.

Occupational therapists are often responsible for prescribing wheelchair cushions for their patients. However, occupational therapy practice in this area varies—even between hospitals and rehabilitation centers in the same locale. A search of the literature revealed only two articles that addressed occupational therapy prescription practices regarding wheelchair cushions. One described the development of a system to individualize the prescription of wheelchair cushions (1); the other described various categories of wheelchair cushions (2). In their chapter on spinal cord injury, Trombly and Scott (3) mentioned weight shifts to relieve ischial pressure, and, in their chapter on mobility and wheelchairs, they described wheelchair cushions. However, to prevent decubitus ulcers, this description is incomplete and obsolete. There are some references to pressure sore prevention in the revised edition of this work (4), but the most current information on wheelchair cushions or selection criteria is lacking.

An overview of the physiological and clinical factors that result in pressure sores and of the wide variety of pressure relief devices available will enable therapists to make objective recommendations concerning this vital piece of rehabilitation equipment.

The understanding of the etiology of pressure sores has not been widely transferred to practical solutions that accommodate daily activity patterns. Similarly, information on the design of technological aids that effectively reduce an individual's risk of developing a sore is not adequately disseminated.

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This paper identifies and describes (from a historic perspective) devices prescribed to relieve pressure for individuals in wheelchairs.

**Historical Evaluation of Pressure Relief Devices**

**Physiological Basis and Natural History of Pressure Sore Development**

As early as 1930, Landis (5) determined mean blood pressure in single capillaries to be 32 mm/Hg in the arteriolar limb, 20 mm/Hg at the midcapillary region, and 12 mm/Hg at the venous limb. These measurements became the reference points for later research in capillary occlusion secondary to pressure. In 1958, a study of 11 normal subjects we evaluated on several seat surfaces determined that ischial pressures were generally more than 300 mm/Hg on flat padded and unpadded surfaces and on an unpadded contour surface (6). If a 5-cm (2-in.)-thick foam pad was added to the flat surface, the pressures dropped to 160 mm/Hg. Only a prototype alternating pressure contour chair produced intermittent reduction of pressure to levels in the range of the capillary blood pressure as described by Landis. However, this chair was not developed for the commercial market.

Kosiak (7), often considered the father of modern pressure sore research, defined pressure sores as localized areas of cellular necrosis. He produced sores in dogs by compressing soft tissue over bone in dogs and then measured the pressure at the interface of the body and the compressing device. From this he concluded that ischemia, resulting from supracapillary pressures, was one of the main causes of ulceration. In an earlier publication, Kosiak (8) reported that pressure ulcers were the result of ischemic, neurotrophic, and metabolic factors. Ulcers almost always occurred in the tissue that overrode a bony prominence. When pressure exceeds tissue capillary pressure, ischemic changes result in ulceration. Neurotrophic changes, such as those that occur in spinal cord injury, result in diminished or absent sensation; thus, the patient is unaware of the pressure overload. Although these neurogenic factors may not be primary in the development of ulcers, the patient is nonetheless prevented from the normal protective response to the resulting discomfort. Metabolic factors in ulcer formation include nutrition, edema, and anemia. Problems of infection become systemic, and specific procedures for treatment become essential. Therefore, pressure sores do not result from isolated incidences but rather from several mechanisms acting systemically.

The purpose of Kosiak's (8) work was to measure the time and pressure necessary to produce necrosis under controlled conditions. He found that intense pressure of short duration was as injurious to tissue as was lower pressure applied for longer periods of time. His study also showed that all the tissue from the skin to the bone was subjected to enough pressure to result in changes. Kosiak found that degeneration at all levels occurred simultaneously. Microscopic degenerative changes occurred even from relatively low pressures. However, in cases of excessive pressures, complete relief of pressure often restored normal cellular metabolism. One to two hours after pressure was applied was the critical time during which pathological changes occurred in normal and denervated skeletal muscle.

Dinsdale (9) experimented with swine because the tissue structure of swine is closer to that of humans than is the dogs' used by Kosiak. Dinsdale found that friction increased the susceptibility to skin ulceration at constant pressures of less than 500 mm/Hg but that friction and repetitive pressure of only 45 mm/Hg also resulted in skin ulceration. He found that decubitus ulcers were not totally the result of an ischemic mechanism but that friction was a factor in the pathogenesis of ulcerations because it applies mechanical forces in the epithelium. He also described an inverse relationship between the magnitude of pressure and the duration of tolerable pressure that produced decubitus ulcers.

Keane (10) supported the fact that ischemic muscle necrosis due to pressure occurs before skin death. Today, many clinicians recognize that the pressure sore visible on the surface of the skin is like the tip of an iceberg, the tissue damage is far greater and closer to the bone. Daniel, Priest, and Wheatley (11) contradicted Kosiak's (8) work, which showed that degeneration of tissue occurs simultaneously at all levels, including the skin. These investigators found that the pathological changes were initially in muscle but then progressed toward the skin with an increase in pressure and/or prolongation of time. Therefore, they concluded that the primary pathological problem was the inability of the tissue to respond to external pressure because of tissue wasting associated with paraplegia (atrophy of the soft tissue coverage), repeated trauma (pressure loads), and/or infection (tissue necrosis secondary to infection).

Regardless of the philosophy, it is clear that the ulcerations can have long-lasting effects on the in-
individuals. Attempts to apply these scientific efforts to the clinical setting have not been consistently successful because the instruments used in these studies were not always applicable to human subjects. It is important, therefore, to identify the traditional, clinical interventions aimed at prevention.

**Clinical Basis of Pressure Sore Prevention**

**Nonmechanical interventions.** Procedures of good nursing care, especially during the acute phase of hospitalization are the major deterrents to pressure sore formation (12). These procedures include turning patients in bed, positioning them for pressure relief in the supine, sidelying, and prone positions, inspecting patients' skin, avoiding shearing forces on the skin (friction), maintaining cleanliness, and providing good nutrition.

The routine turning of patients is critical. Guthrie and Goulian (13) considered turning of primary importance in pressure sore prevention. Dowling (14), McElhinney (15), and Pinel (16) described a turning regimen of every two hours: first on one side, then on the back, and finally on the remaining side. Morley (17) and Rogers (18) emphasized the dangers of shearing (friction) forces that occur when the patient is dragged instead of lifted. Recent developments in the design and manufacture of special beds may reduce the risk of shearing, but more scientific investigations are necessary. Morley (17) recommended that the head of the bed be raised only for meals because gravity and the resulting shearing force or friction between the sacrum and the bed surface cause damaging tissue erosion.

Cress and Busza (19) stressed the importance of adequate nutrition, which includes a high-protein and high-vitamin diet. They believed that the metabolic changes which occur as the result of trauma and/or disease required maintenance of adequate caloric intake.

The importance of good hygiene was discussed by Schell and Wolkott (20) and Gale (21). Clean, dry, and smooth bed sheets are mandatory. Attention to bowel and bladder function was important to prevent the patient from lying in waste that could irritate or infect already stressed tissue.

As early as 1969, a team of plastic surgeons advocated a program of activities that, when individualized for each patient, would prevent pressure sores in paraplegic persons (22). The program included complete coordination and cooperation of efforts between the nursing personnel, the family, the physician, the social worker, and the patient.

**Mechanical interventions.** Good nursing care did not seem to be enough. Clinicians began to look for devices for pressure sore prevention. Protective devices, such as sheepskin, rubber or plastic air rings, and rubber foam became available for use in either the bed or the wheelchair. However, there is no evidence that these items prevented pressure sores. Unfortunately, early methods of evaluating differences in these devices were not always accurate. For example, in 1965 a spring compression device was designed to measure contact pressures of normal subjects in the lying and sitting positions (23). Highest pressures were observed under the ischial tuberosities when the subjects were sitting. However, the device was impractical for use in monitoring disabled people.

Bush (24), used a single pressure-sensitive transducer connected to a readout component to measure ischial pressures as the position of the subject's legs was varied. He found that ischial pressure was significantly higher when the feet were supported but that there was no difference in pressure when the feet were hanging free or when the legs were extended and supported at the calves. Unfortunately, this pressure measuring device, which was expected to be clinically useful, was not further developed.

Houle (25) evaluated the pressure under the buttocks of ten normal subjects seated on the following seven surfaces: plywood, a wheelchair sling seat, a cut-out 7.5-cm (3-in.) plastic foam, an inflatable rubber contour pad, a synthetic viscoelastic pad on a sling seat with a board and a 2.5-cm (1-in.) foam pad, a mechanical drop seat, and an alternating air pressure pad. To measure pressure he used devices similar to those of Kosiak: pneumatic butterfly valves, miniature transducers, and pneumatic cells arranged to provide a pressure matrix of the buttocks. Houle found the greatest pressure under and posterior to the ischial tuberosities. Ischial pressures ranged from 140 mm/Hg on the board to 80 mm/Hg on the viscoelastic gel. He concluded that although the seats redistributed pressure, they did not sufficiently reduce pressure below capillary pressure; therefore, none of the devices tested was successful in preventing ischemic ulcerations.

Mooney, Einbund, Rogers, and Stouffer (26) developed a pneumatic cell pressure sensor to evaluate the pressure distribution qualities of 12 commercial cushions. None of the cushions was able to reduce tissue pressure to below arterial capillary pressure. These researchers concluded that pressure distribution is the most important characteristic of seat cushion design. An ideal cushion, in their opinion, would distribute pressure...
evenly over the largest skin area, be lightweight, require little maintenance, be low in cost, and have a durable cover. However, no cushion met all these criteria.

In 1973, Cochran and Slater (27), in conjunction with the Veterans Administration Prosthetic Center, evaluated the biomechanical characteristics of 12 cushions made from foams, gels, water, and viscoelastic materials. The purpose of their study was to develop practical cushion evaluation techniques and standards, the first such attempt to emphasize clinical conditions in test programs. In general, the foam cushions received favorable scores for pressure relief, whereas gel cushions (which were stiff) produced unfavorable sitting scores. Water cushions produced the lowest pressures but were considered impractical for long-term clinical use. During the clinical phases of testing, the researchers encouraged the use of six miniature pressure transducers. They critically evaluated their own methodologies and found them to be insufficient in terms of limitations imposed by the available test equipment. However, they were able to obtain reproducible differences between cushions.

In 1974, Souther, Carr, and Vistnes (28) evaluated 20 normal subjects on 22 cushions and on the wheelchair sling seat. The cushions were air-filled, rotation, or foam. Ischial pressures were monitored through a surface pressure manometer. These investigators concluded that no cushions reduced mean pressures below mean capillary pressure and that such a reduction may be unattainable. Furthermore, they believed that no mechanical device should be expected to replace the scrupulous attention to skin care and conscientious adherence to repositioning and turning regimens.

In 1976, DeLateur, Berni, Hongladarom, and Giaconi (29) observed hyperemia as an indication of impending tissue breakdown. They found no significant differences among seven commercial cushions in reducing reactive hyperemia in three paralyzed subjects. They concluded, therefore, that patients with paraplegia could not sit motionless for 30 minutes without some degree of reactive hyperemia occurring. Thus, the researchers recommended weight shifting of patients several times an hour.

From the above studies it became apparent that pressure measuring devices to evaluate wheelchair cushions did not give enough objective data on the magnitude and overall distribution of pressure, nor were such devices practical in the clinical environment. In 1978, Garber, Krouskop, and Carter (1) described a system to clinically evaluate wheelchair cushions. This system, called the Pressure Evaluation Pad (PEP), was designed to clinically quantify pressures under a seated or reclining subject. Results of this work indicated that none of the six commercial cushions tested was effective in reducing pressures and that individual evaluation was essential for maximum benefit and protection against pressure sores. Nelham's (30) survey of the pressure relief properties of seven devices supported the principle of individual evaluation. His survey reconfirmed the lack of technology to adequately assess friction and pressure.

Despite the efforts of conscientious investigators to quantitatively and objectively measure pressure and its distribution under the seated wheelchair patient, there is still much controversy and disagreement concerning the accuracy and clinical usefulness of such measurements. Most of the pressure-measuring devices designed for specific research endeavors were not developed to withstand the stresses of routine clinical use; therefore, few of these devices became available commercially for use by therapists and physicians in the clinical environment. The small pneumatic pressure evaluator of Rogers (31) was used successfully in a tissue pressure clinic at Rancho Los Amigos Hospital but was found to be less reliable at other centers. The large pneumatic matrix pressure evaluator described by Garber et al. (1) had clinical validity but was not consistently reliable with daily clinical use.

Doubts still existed as to the accuracy of the pressure readings (usually measured in mm/Hg) during a wheelchair cushion evaluation. Graebe (32) rejected the validity and reliability of some of the pressure-measuring devices because they failed to completely conform to the shape of the cushion. However, this “hammocking” effect was described in 1981 by Denme (33) and found not to interfere with the effectiveness of either the cushion or the measuring devices. These differences in opinion and methods should be considered in future research efforts to identify the etiology, treatment, and prevention of pressure-induced tissue trauma.

Classification of Wheelchair Seating

Wheelchair cushions are used to relieve pressure and to distribute the body's weight away from the areas vulnerable to tissue erosion. The anatomic parts at risk for a person in the sitting position in-
clude the ischial tuberosities, coccyx, sacrum, and the trochanters. Wheelchair cushions are also used to stabilize the body for balance and provide comfort to the seated individual. In recent years, hundreds of commercially available wheelchair seating devices have been developed, creating the need for therapists to better understand the devices. These pressure-relief devices, classified by Garber (2) in 1979, can be subcategorized into dynamic and static devices (see Figure 1).

**Dynamic systems.** These are seats that depend on an external power source for activation, ostensibly to relieve pressure areas cyclically. They are not used extensively by individuals with spinal cord injury, because they are cumbersome and rely on compressors or other such power supplies. These factors may limit mobility for the user, as discussed by Key, Matley, and Wakefield (34).

**Static wheelchair cushions.** These are seat cushions placed in the wheelchair and they relieve pressure because of their design and the material of which they are made. They are divided into three categories: air-filled, flotation, and polymer foam (2).

Air-filled cushions are lightweight and easy to clean. However, they are subject to puncture and require the user to monitor the air pressure. Examples of air-filled cushions include the ROHO Dry Flotation Cushion and the Bye-Bye Decubiti Cushion.

Flotation cushions are of two types: gel and filled, and are designed to adjust to the body's movement or to simulate fat tissue to provide adequate protection from pressure. They are usually easy to clean but are heavy and difficult to transfer, and they must be stored flat. Some individuals who use a gel cushion for a long period of time may lose tolerance to other types of cushions. [This is significant only if the person has developed pressure sore problems and needs an alternative device.] Examples of flotation cushions include the Aqua-Seat, Stryker, Reston, Elasto-gel, and Jobst.

Polymer foam cushions constitute the largest category and are the most versatile because they can be cut into any size, shape, or thickness. They are usually lightweight and are less expensive than the other cushions. Foams of different thicknesses and densities can be glued together for an individualized fit. However, foam cushions have two major disadvantages. First, they cannot be washed or cleaned because soap and water or other cleaning solutions reduce the pressure-relief and supportive properties of the material. These cushions are also affected by air pollution, heat, and light and deteriorate with time even if not subjected to body weight pressure. Second, foam cushions wear out more rapidly than do other types; their average life span is only six months. It should be noted that worn-out wheelchair cushions are responsible for tissue pressure problems in many individuals that have spinal cord injuries. The trend has been away from foams for individuals with long-term disability because of the foam's relatively short life-span compared to other materials. Examples of foam cushions include the Stainless Foam Cushion and the Jay Cushion (a combination of foam and gel). Therapists who prescribe these devices must be familiar with the characteristics of the cushions so that rational recommendations can be made.

**Summary of Wheelchair Cushion Prescription Practices**

Before 1970, wheelchair cushions were usually prescribed by the rehabilitation or medical team on an arbitrary basis. Most were foam and gel cushions, although some air cushions were also available. In many hospitals, patients were seated on rubber or plastic air rings or rubber "donuts."

Little was known about the usefulness or effectiveness of these devices because there was no clinical
method of evaluating them. Furthermore, few clinicians correlated the occurrence of pressure sores with the wheelchair cushion. Although some researchers studying the effect of pressure on tissue developed instruments to measure pressure, only a few of these devices were practical and usable in the clinical setting. Therefore, clinicians in hospitals and rehabilitation centers developed their own preferences without the benefit of scientific evidence that might have influenced the prescription of such devices. In addition, a patient’s body build was found to influence the magnitude and distribution of pressure; much variation in pressure between different cushions under the same patient and between different patients on the same cushion was observed (35).

The prescription of a wheelchair cushion is not determined by pressure measurements alone (36), partly because of the limited number of available evaluation devices. However, even with such devices other factors must be considered. These include the patient’s diagnosis and upper extremity function; postural defects, such as scoliosis, lordosis and kyphosis; the number of hours the patient spends in the wheelchair each day; the kinds of activities the patient performs from the wheelchair; the proposed usage environment, such as climate, pollution, humidity, temperature, and terrain; and the patient’s living arrangements, independent or dependent; the patient’s tissue history, such as the presence of pressure sores, surgery to correct ulcers, or decreased sitting tolerance secondary to specific medical or social factors; the patient’s body build (the pressure relief needs of thin patients are different from those of heavier individuals); the wheelchair itself, with impact loads and usage environment that affect wheelchair suspension systems; psychosocial factors, such as a patient’s attitude, interest, and motivation; and, of course, pressure and its distribution.

Cushions prescribed during the early phases of rehabilitation may not be the device that an individual will use when he or she returns to the family, community, and vocational, educational, and social activities. Foam cushions are often prescribed at this time because they are less expensive, lightweight, provide stability, and pressure reduction, at least initially. A gel cushion may be recommended for use in the automobile although it is generally heavy and not suggested if the individual must transfer it frequently.

Conclusions

Occupational therapists are concerned with maximizing functional potential in patients with physical disabilities and recognize that pressure sores greatly interfere with that objective. Many occupational therapists are directly involved in the prescription of wheelchair cushions for patients in rehabilitation centers, nursing homes, and hospitals. The professional basis for the practice of occupational therapy is derived from both an appreciation and an understanding of the body of literature relating to that practice and the development efforts to produce improved future practice. The purpose of this historical review was to present a specific problem, discuss the nature of the critical thinking regarding potential solutions, and describe the development of therapeutic mechanisms to alleviate the problem. Furthermore, it proposes potential therapeutic interventions for future evaluation.

The studies reviewed indicate that the following three major mechanisms cause tissue breakdown and formation of pressure sores in patients with physical disabilities.

1. Metabolic and nutritional inadequacies, which are a frequent concomitant of chronic illnesses, diminish tissue repair and may even induce tissue wasting. Therefore, loss of adipose tissue and muscle mass result in the malnourished patient. This, in turn, diminishes the area through which the pressure of a bony prominence can be diffused. As a result, localized high pressure, combined with poor tissue repair, causes capillary occlusion and tissue necrosis.

2. The inadequacies of nursing care and of patient positioning constitute an independent mechanism contributing to the development of pressure sores. Irrespective of the nutritional state of the patient and the application of pressure relief devices, prolonged pressure on any single area will ultimate produce changes in the skin surface, thus undoing the best efforts of the entire rehabilitation team.

3. Inadequacies of pressure relief devices may be difficult to discern in the clinical setting. Although a broad spectrum of pressure-relief devices made of different materials has been developed, none of the devices has been more efficacious for the entire population at risk or for any subpopulation studied. Despite extensive physiological and clinical investigations, present technology is still inadequate to satisfactorily assess friction and pressure.

Although foam cushions may be the initial pressure relief device of choice, they may not be optimally
effective in reducing pressure once an individual has left the hospital environment. Observations of patients who developed tissue breakdown while using foam cushions suggests that alternative cushions are more effective for pressure reduction in the majority of such cases. Patients that have tissue breakdown urgently need a detailed and individualized clinical evaluation to determine which pressure-relief device is the most effective for them.

Regional, philosophical, clinical, and scientific differences in the selection of wheelchair cushions for individuals with physical disabilities continue. However, no universal cushion exists that can relieve, or at the least reduce, pressure for all groups. Future research should address the development of better evaluation tools and better mechanisms for the dissemination of information rather than the development of the "perfect" cushion.

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