WHEELCHAIR SEATING

A State of the Science Conference on Seating Issues for Persons with Disabilities

Orlando, Florida
February 19-20, 2001

Sponsored by NIDRR
and the
Rehabilitation Engineering Center on Wheeled Mobility
at the University of Pittsburgh

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Executive Summary

The state of the science conference, Wheelchair Seating, was a consensus conference for determining the research and development priorities in four major areas related to wheelchair seating: *Tissue Integrity Management*, *Wheelchair Transportation Safety*, *Postural Control*, and *Wheelchair Seating Comfort*.

The conference, sponsored by the Rehabilitation Engineering Center on Wheeled Mobility and the National Institute on Disability and Rehabilitation Research, brought together participants with a myriad of interests related to wheeled mobility and seating issues. The 48 participants from Europe and North America were researchers, educators, manufacturers, service providers, clinicians, funding sources and consumers.

Each session of the two-day conference began with presentations by the core topic keynote speakers. Participants then divided into two separate working groups for each core topic.

Following the breakout sessions, participants reconvened as a whole for discussion aimed at prioritizing and refining the research priorities identified by the working groups. Grand summaries of the breakout sessions and prioritizations of the results are included in the section on Session Notes and Priorities.

Due to the varied nature of the background, experience and priorities of conference participants, a number of issues were viewed from divergent points of view. However, there were also salient points for which there was a great deal of consensus.

Highlights of consensus points for each of the four core topics, in no particular order related to priority, are included below.

Tissue Integrity Management

Pressure ulcers are a significant healthcare problem for wheelchair users. Unfortunately, the mechanisms underlying the etiology of pressure ulcers are not well understood.

A variety of measurement techniques have been used to investigate the many factors and markers thought to be related to pressure ulcers. The interpretation of clinical research is complicated by a lack of standardized methodologies.

The lack of standardized methodologies limits the strength of evidence provided by past research. The lack of evidence in the literature also is reflected in the barriers to appropriate coding policy and, therefore, clinical application of appropriate seating interventions.

Wheelchair Transportation Safety

Wheelchair seating systems are key to providing adequate protection to wheelchair users in the event of a crash. Voluntary industry standards have provided the first critical steps toward improved wheelchair user crash protection, but education of consumers, clinicians and manufacturers is essential for effective standards implementation.

As compared to the motor vehicle industry, little research has been conducted related to the effects of wheelchair and wheelchair seating design on occupant protection and injury risk. Test methods are needed to evaluate wheelchair seating independent of a specific frame.

While voluntary industry standards provide test methods, design guidelines, labeling and instructions for adult users, wheelchair seating design criteria is also needed for pediatric wheelchairs.

Preliminary guidelines for wheelchair seating (not including the seat back) have been developed using computer simulation and limited sled impact testing. Additional design guidelines, testing (frontal, rear and side impact), researchers and research training are needed to develop and provide consumers with transport-safe wheelchair products and to advance the wheelchair transportation field.

Seating for Postural Control

There is little evidence-based practice addressing seating/mobility concepts for persons who experience abnormal tone. A definition of "good" posture and how it impacts function is needed to provide a better understanding of the effects of seating intervention on issues

such as the progression of postural deformity, swallowing, respiration, digestion, and cardio-pulmonary status.

Persons with high tone are of all ages and have various functional needs. Standardized measures of posture and function while seated would assist clinicians and researchers in developing outcome measures to compare effectiveness, and documenting changes in deformity, function and posture over time. Standards would assist in the prediction of technology choices and realistic long-term planning.

The service delivery system, and funders in particular, do not recognize the complexity of providing seating to people with advanced needs. Reimbursement for positioning programs or training in the use of the technology is not common practice and insufficient time is allotted for assessment and evaluation of people with high tone and complex needs.

People with abnormal tone have multiple needs and their seating systems must provide enough stability to support limited motor control. Few seating/wheelchair components on the market can survive without breakage for persons with high tone. Because of the frequency and strength of extensor thrust, seating parts must be extremely strong and anchor points reinforced. At the same time, systems need to be easily adjustable to accommodate changing posture since, for persons with CHI, tone can change rapidly over the first years post injury.

Similarly, asymmetry often demands aggressive midline positioners; these need to be securely mounted so as not to move when the person experiences high tone episodes and yet also removable or able to swing away for transfers or management. Unfortunately, components and seating practices are often at odds with each other.

Research is required to better understand the frequency, force and natural history of episodes of high tone. As we better understand the effects of dynamic components on spasticity, more appropriate options will follow.

Wheelchair Seating Comfort

Wheelchair seating comfort has been identified as a priority in a number of studies. Yet there seems to be little agreement among ergonomists or disability researchers as to how best to quantify discomfort or produce tools that can reliably link feelings of discomfort with qualitative indicators, such as surface interface pressure. There is a semblance of agreement that the sensation of discomfort is complex and multi-factorial in nature.

Discomfort problems lead to reduced participation in the activities of daily life yet the need for comfort is not considered a legitimate clinical need. Consequently, it is not funded by most third party payers and products with discomfort-relief features have not become routinely available.

The population most in need of relief from seating discomfort is wheelchair users with near normal sensation but a lack of sufficient motor function to relieve discomfort. Current wheelchair technology is designed mainly for pressure relief for high level spinal cord injured persons and does not adequately meet the needs of the aforementioned target population.

Historically, relatively little research effort has focused on disability and seat discomfort. There has been extensive research and development on comfort in office and automotive seat products, thereby leading to commercial successes. The findings which led to these successes have yet to be routinely applied to wheelchair seating.

Tissue Integrity Management

STATE OF THE SCIENCE WHITE PAPER ON TISSUE INTEGRITY MANAGEMENT

David M. Brienza, Mary Jo Geyer, Patricia Karg and Yih-Kuen Jan

Introduction

Unrelieved pressure upon weight-bearing tissues can produce lesions, identified by their etiology as pressure ulcers (AHCPR, 1992). The prevalence of pressure ulcers for elderly nursing home residents has been estimated between 2.3% and 28%. (AHCPR, 1992; Brandeis, 1995; Smith, 1995; Young & Burns, 1981). The prevalence rate among other populations with mobility impairments is even higher; it has been estimated that between 50% and 80% of persons with spinal cord injury will develop a pressure ulcer (Gosnell, 1973; Richardson & Meyer, 1981; Rodriguez & Garber, 1994; Salzberg, 1996). Even the lowest of these estimates aptly demonstrates that pressure ulcers are a significant health care problem.

According to 1999 Health Care Financing Administration (HCFA) data, inadequate attention to prevent pressure ulcers was the most frequently cited quality of care deficiency in the long-term care setting (Lyder, 2000). The costs associated with the management of pressure ulcers in the U.S. exceed $6.4 billion annually (Marwick, 1992). This burden is reflected in health policy as Healthy People 2010 includes the measurable prevention objective of decreasing pressure ulcer prevalence 50% by the year 2010 (NPUAP, 2000).

Sitting-acquired pressure ulcers are a particularly significant problem for wheelchair users. The percentage of pressure ulcers caused by sitting in wheelchairs is difficult to ascertain, but estimates in the literature suggest that it is between 36% and 50% for the at-risk elderly population (Zacharkow, 1984). The inadequacy of wheelchair fit contributes to the development of pressure ulcers (Zacharkow, 1984; Lim, 1988). In assessing risk, individuals with mobility impairments that prevent independent repositioning, as well as those that are bed and chair-bound, tend to be at the greatest risk for pressure ulcer development (Allman, 1997).

Several studies have indicated that the use of pressure-reducing wheelchair seat cushions designed to maintain tissue integrity will reduce the incidence of sitting-induced pressure ulcers (Bardsley, 1984; Conine, 1994; Geyer, 2001; Lim, 1988; Shaw, 1993; Shaw, 1996). Tissue integrity is maintained by reducing pressures near bony prominences, accommodating orthopedic deformities through immersion, enveloping irregularities at the seating interface to reduce high pressure gradients, and controlling heat and moisture.

Review of the Science

While most agree that the primary cause of pressure-induced tissue necrosis is occlusion of capillary blood flow resulting in an ischemic injury (Kosiak, 1961), the impairment of lymphatic drainage and/or interstitial fluid flow have also been proposed as primary causes of pressure ulcers (Krouskop, 1978; Krouskop, 1983; Reddy & Cochran, 1981). Nonetheless, external pressure has long been the focus of etiological investigations on the mechanics of pressure ulcer formation (Crenshaw & Vistnes, 1989; Kosiak, 1961). Pressure measurements are also common in clinical settings where support surfaces are evaluated relative to their potential for risk of pressure ulcers. Other mechanical factors studied include pressure gradient, shear force, and tissue deformation, although investigations studying these factors are far less common than those focusing on pressure alone.

While considering the pressure ulcer problem it is important to note that factors other than mechanics influence pressure ulcer formation. Many interrelated factors, intrinsic as well as extrinsic, have been shown to predispose load-bearing tissue to mechanical damage (Crenshaw & Vistnes, 1989). An extended accounting of pressure ulcer formation must include not only mechanical factors as a primary causative agent, but also other contributing agents such as friction, heat, moisture, incontinence, malnutrition, and an altered level of consciousness (AHCPR, 1992; Evans, 1995; Mawson, 1993). The importance of these various factors also depends upon the particular patient population considered. For example, persons with spinal cord injury are at greatest risk subsequent to loss of sensory and motor functions, loss of vasomotor control and tone, changes and abnormalities in mor-phology of bone and soft tissue, and altered neuromuscular activity (spastic or flaccid) (Ferguson-Pell, 1990; Mawson, 1993; Rodriguez & Garber, 1994). Salzberg followed 219 individuals with SCI for six years and found that 176 (80.4%) had a history of at least one pressure ulcer (Salzberg, 1996).

The mechanics of pressure ulcer formation are characterized by several key elements including the magnitude, direction and the distribution of forces over the body surface and the tissue deformations associated with those forces. Extrinsic pressure acting upon weight-bearing tissue is defined by the distribution of forces over an area of tissue. The direction of forces ranges from perpendicular to the tissue surface to tangential to the tissue surface. The typical loading conditions will include a combination of normal and shear forces. The forces on the surface of the tissue are transmitted into the tissue

and cause deformation, resulting in internal stress and strain of the tissue that can lead to necrosis. As such, tissue deformation is seen as a measure of the net effect of these external reaction forces (Brienza, 1993; Levine, 1990; Reddy, 1981).

Coincidentally with tissue deformation is an increase in internal tissue pressure levels. The levels of internal pressure are dependent upon the heterogeneous mechanical properties throughout the soft tissues and the directions in which these tissues are distended by the applied loading. If the tissues are confined so that no redistribution of tissue mass can occur or if loading is applied hydrostatically, the soft tissues can withstand relatively high pressures without significant risk of tissue damage (Levine, 1990). Only when pressure is applied non-uniformly are tissues strained and consequently put at risk of tissue damage. While sitting, the soft tissue of the buttocks is not contained; therefore, support surface reaction forces can result in internal strain and ischemia. If excessive forces are not relieved, the result is often morbidity and ensuing tissue necrosis. The variability in normal forces is sometimes described as vertical shear (Bennett, 1984) or is quantified in terms of "gradients" of force or pressure (Garber & Krouskop, 1982). As vertical shear increases, the probable effect is an increase in the deformation of the tissue and, therefore, in the risk of tissue damage.

Much previous research has been directed at attempts to establish an interface pressure threshold beyond which pressure ulcers will form. Interface pressure has been used extensively as a tool for predicting the clinical effectiveness of various support surfaces and for comparing products. The validity of this approach, however, has come into question as a wide range of interface pressures have been found to occlude capillary flow. Values ranging from 11 to 120 mmHg have been shown to have this effect (Clark, 1988). More recent research has gone beyond assuming that tissue necrosis is a result of ischemia due to external pressure alone.

A number of techniques are available to assess the effects of pressure on tissue responses, including measurements of transcutaneous oxygen tension ($TcPO_2$), Laser Doppler flowmetry (LDF), photoplethysmography, thermography, transcutaneous and in vivo biochemical analyses, ultrasound propagation properties and various imaging techniques. Current investigations are focusing on the physiological, biochemical and biomechanical characteristics of tissue and their interactions.

$TcPO_2$ quantifies the tissue oxygen tension as oxygen diffuses from the dermal capillaries through the epidermis to the skin surface. This technique requires the application of external heat (approximately 44 °C in adults); the heat dilates the dermal capillaries and reduces the resistance of the stratum corneum to oxygen diffusion (Tremper, 1984). $TcPO_2$ has been used as a measure of the perfusion of the skin in response to external loading (Bader & Gant, 1988; Goossens, 1994; Liu, 1999; Sangeorzan, 1989; Xakellis, 1991). Bader and Gant recorded $TcPO_2$ levels of a mixed group of elderly subjects to applications of prolonged external loads. The results demonstrated great variability among subjects in the level of applied pressure required to significantly reduce $TcPO_2$ (Bader & Gant, 1988). Liu et al. recorded $TcPO_2$ levels in subjects with tetraplegia with and without pressure ulcers. The results showed pressure ulcer sites of tetraplegia with pressure ulcers have lower $TcPO_2$ levels than that of tetraplegia without pressure ulcers. Accordingly, they proposed $TcPO_2$ may be an effective method to identify individuals with high susceptibility to pressure ulcers.

LDF measures the capillary blood flow of the skin 0.6 to 1.5 mm below the surface (Öberg, 1990). It utilizes the Doppler shift of laser light backscattered from moving red blood cells to provide a continuous and non-invasive measure of blood flow in the tissues. LDF has also been used as a measure of skin perfusion (Abu-Own, 1995; Ek, 1984; Mayrovitz, 1993; Sanada, 1997; Schubert & Fagrell, 1991; Xakellis & Frantz, 1990). Schubert and Fagrell used LDF to demonstrate spinal cord injured subjects have impaired postocclusive reactive hyperemia and temperature response to locally applied pressure over the sacrum and the gluteus maximus. Some recent studies have measured per-fusion with both $TcPO_2$ and LDF techniques (Colin & Saumet, 1996; Sachse, 1998; Xakellis, 1991). Of note is the finding by Xakellis that LDF continued to decline beyond the point where $TcPO_2$ reached zero. This may indicate that interface pressures lower than those causing capillary closure may also lead to tissue hypoxia (Xakellis, 1991).

In 1990, Bader used $TcPO_2$ to monitor changes produced by the application of various loading regimens to the sacrum and ischial tuberosities of normal and spinal cord subjects (Bader, 1990). In 1997, Sanada used LDF to monitor pressure-induced changes in blood flow over the bony prominences of surgical patients (Sanada, 1997). Both studies revealed a normal response to pressure as an increase in perfusion that has been recognized as *active* hyperemia. However, this response only occurs in low interface pressure (Bader, 1990; Frantz, 1989; Herman, 1999; Mayrovitz, 1993; Patel, 1999; Sanada, 1997; Xakellis, 1993). Abnormal responses (a failure to increase perfusion in response to pressure) have been explained in terms of impaired vasomotor response. The results of these investigations reflect the limitation of using interface pressure as a sole indicator of

threshold for pressure ulcer formation.

Reddy et al. investigated the effects of external pressure on interstitial fluid dynamics by using a mathematical model. According to their theoretical model, for a given pressure, the time in which the interstitial fluid volume decreases by half represents the tolerance time/threshold for pressure ulcer formation (Reddy, 1981a; Reddy, 1981b). The similarity between the pressure-time relationships of Reswick and Rogers and the interstitial fluid volume-pressure-time relationships observed by Reddy support the theory that slow viscous flow of interstitial fluid and ground substance play a role in tissue necrosis (Reddy, 1981a; Reswick & Rogers, 1976). Utilizing the same mathematical model, Reddy et al. Proposed that it was the pressure gradient that induced the flow of interstitial fluid and, thus, they proposed that pressure gradients may be more significant in pressure ulcer etiology than interface pressure (Reddy, 1981a). The work of Swain et al. demonstrated that pressure gradients were indeed proportionally larger in subjects with the highest interface pressure readings (MDA, 1997).

Attempts to monitor the interstitial fluid pressure in the soft tissues using the wick-catheter technique followed. Reddy et al. believed that the collagen network supports a substantial portion of the externally applied load with only a fraction of the load being transmitted to the interstitial fluid (Reddy, 1981a). In general, this study indicated that the relationship between the external load and the interstitial fluid pressure at 2-5 mm below the skin was a non-linear one, i.e., the interstitial fluid pressure tended to be lower than the external pressure. Reddy et al. propose that when interstitial fluid is squeezed out of a tissue region, direct contact of the cells induces stresses that may cause rupture and interrupt vital cell functions including collagen synthesis. This breakdown would continue even after the load was removed (Reddy, 1981a).

Reddy also believes that lymphatic flow could be impeded by mechanical stresses and/or the lymphatic vessels themselves might be damaged in response to excessive fluid flow. Subsequent accumulation of metabolic waste products may lead to tissue necrosis. The research of Miller and Seale support this theory (Miller & Seale, 1981). Isotopic (technetium) techniques enabled them to trace the radioactivity in dog hind limbs during external compression with a dead weight cylindrical device. The lymphatics cleared the tracer from the interstitial fluid until the external pressure reached 60-70 mmHg, then lymph flow decreased to zero with further increases in pressure.

Recent investigators also note the importance of biochemical responses. Transcutaneous biochemical analysis such as sweat analysis has been investigated by Polliack et al. (Polliack, 1993 & 1997; Knight, 2001; Taylor, 1994). Based on the hypothesis that metabolites concentrations may be used as an indicator of soft tissue damage, they collected thermally induced sweat following the application of different loading regimens on the forearm, ischial tuberosity, and sacrum of normal subjects. Results indicated that tissues subjected to pressure ischemia produced a general increase in concentrations of lactate, chloride, urea and urate as well as a decreased sweat rate (Polliack, 1993). Polliack et al. use this technique to investigate the sweat metabolites in debilitated subjects. Results indicated that lactate and urea concentration increased after prolonged low level pressure (Polliack, 1997). Combined with the $TcPO_2$ tool, Knight et al. demonstrated that tissue oxygen level may be a critical factor in tissue metabolism (Knight, 2001).

Measurements of circulating plasma levels of mediators of immunoactivation (ICAM-1 and IL-2*R*) were measured in able-bodied subjects, spinal cord injured subjects without pressure ulcers, and spinal cord injured subjects with pressure ulcers by Segal et al. (Segal, 1997). Results indicated that the spinal cord subjects with pressure ulcers had the highest levels of such markers of inflammation. The authors contend that these easily quantifiable mediators may have diagnostic, prognostic and therapeutic value in predicting or differentiating subgroups of patients who will vary in the severity or the healing of their wounds (Segal, 1997).

The mechanisms underlying the etiology of pressure ulcers apparently are not well understood and the elucidation of the relative significance of the physiological, biochemical and biomechanical mechanisms will require multidisciplinary research. Therefore, while interface pressure may aid in selecting the best support surface for a specific individual based on that individual's relative responses, interface pressure alone is not sufficient to evaluate the efficacy of a particular device or class of devices. Many factors make the results of support surface studies difficult to compare. For example, the testing protocols, test postures, techniques used to measure interface pressure and the sampling groups vary considerably. Lack of knowledge regarding additional tissue responses makes it difficult to determine which parameters should be assessed to determine the efficacy of specific interventions. While efforts to standardize the performance characteristics of support surfaces are in progress, for now the best evidence regarding the effectiveness of support surfaces appears to be the outcome of a decrease in the incidence of pressure ulcers associated with specific interventions, coupled with multiple measures of tissue response.

Clinical Issues

Contradictions exist in the literature regarding the clinical benefits of commercial cushions designed to reduce the risk of sitting-acquired pressure ulcers. Previous research has not revealed any one cushion that consistently provides the lowest pressure measurements for all subjects (Shaw, 1996; Sprigle, 1989; Garber, 1984). Studies comparing polyurethane foam slabs to custom contoured foam cushions failed to demonstrate significant differences in the incidence of pressure ulcers (Lim, 1988; Conine, 1993). Conversely, a subsequent study by Conine comparing a polyurethane foam slab to the Jay cushion showed a significantly lower incidence of pressure ulcers in the Jay group (25%) compared to the foam group (41%) (Conine, 1994). It is of note that Conine's study included the provision of a seating evaluation and appropriate modifications to the wheelchair. Thus, a higher level of internal validity was attained than in previous studies where the effects of the cushion were confounded with those of the chair. Another recent investigation revealed that higher interface pressure measurements were associated with a higher incidence of sitting-acquired pres-sure ulcers (Brienza, 2001). Brienza et al. found interface pressure measured on wheelchair seat cushions was higher for subjects who developed sitting-acquired pressure ulcers compared to those who did not develop pressure ulcers.

In general, a lack of standard methodology has hampered the interpretation of previous study's results. Additional and more comprehensive clinical trials are necessary to provide the strong evidence required by third party funding agencies and to provide clinicians with the information necessary to make good clinical decisions.

Policy and regulatory issues

As medical devices, wheelchair seat cushions are subject to the general controls of the Federal Food Drug & Cosmetic Act (Title 21 Code of Federal Regulations Part 800-1200). Cushions are classified as either Class I or Class II medical devices and are exempt from premarket notification [510 (k)] requirements if they meet two criteria. First, the cushion may not be significantly changed or modified from its original form as marketed in the U.S. prior to May 28, 1976. Second, no Food and Drug Administration (FDA) regulation requiring a premarket approval application may have been published in regard to the cushion. The majority of new cushions meet these criteria, thus they are referred to as being "grandfathered" and are exempt from premarket approval. When cushions are exempt from the extensive evaluation required for pre-market approval, there is little incentive for manufacturers to determine the functional characteristics of available cushions or to develop objective evaluative criteria.

Under the current Medicare system, new cushions are submitted to the HCFA alphanumeric group for assignment of a billing code. Existing codes differentiate among cushion types by either cushion thickness or component materials. This coding system is limited and does not represent the wide range of products and/or the differentials in manufacturing costs of the various cushions. Although HCFA pricing groups created a new category with a higher reimbursement rate to help ease payment inequities (E0192), few objective criteria and no functional performance standards exist to define this or any of the other categories. Despite the fact that most manufacturers seek E0192 categorization for their cushion products, a recent study revealed that only 20 of the 216 cushions available on the market were coded as E0192 (Sprigle, 2000).

Both the suppliers of the coding policy (HCFA) and the demanders (manufacturers, clinicians and consumers) recognize the negative consequences of the existing system. As a result of these limitations, Medicare beneficiaries are being denied access to medically necessary and clinically appropriate seating interventions, manufacturers are having codes rather arbitrarily assigned to their products with no guarantee of consistency, and clinicians have limited objective criteria with which to discriminate among cushions. The need to modify the existing coding system is apparent. However, both problem definition and the presence of viable solutions are hampered by a lack of research regarding objective cushion criteria and functional performance standards. Although efforts are proceeding in an attempt to solve the problem, the lack of research outcomes in the form of objective criteria and performance standards is proving to be the primary barrier to policy modification.

Decision-making on the part of policymakers, in this case the SADMERC/DMERC medical directors and the alpha-numeric work group, requires a review of the appropriate medical literature to find support for a particular course of action. In the case of the problems associated with seat cushions and pressure ulcers, the evidence in the literature is insufficient. In a 1998 letter to a seat cushion industry group, the SADMERC Medical Advisor stated, "To our knowledge there is no proof from adequate clinical trials that any cushion or any design is superior to any other in producing better health outcomes or that any cushion or any specific feature is associated with better outcomes." (Nelson, 1998) This lack of evidence is due, in part, to the nature of assistive technology research that does not lend itself easily to the traditional medical model of double-blind, cross-over, randomized control trial metho-

dology. The wheelchair user population is diverse and subgroups tend to be small and geographically scattered. This makes conducting clinical trials logistically difficult. In addition, assistive technology research is under-funded in contrast with other areas of medical technology research. Research in assistive technology that is industry-sponsored lacks credibility/objectivity and the FDA pre-market exemption for most new cushions provides little incentive for even this limited industry-sponsored research.

Summary of Findings

- Pressure ulcers are a significant healthcare problem for wheelchair users.
- The mechanisms underlying the etiology of pressure ulcers are not well understood.
- Various measurement techniques have been used to investigate the many factors and markers thought to be related to pressure ulcers.
- The interpretation of clinical research is complicated by a lack of standardized methodologies and thus limits the strength of evidence provided by past research.
- The lack of evidence in the literature also is reflected in the barriers to appropriate coding policy and, therefore, clinical application of appropriate seating interventions.

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Wheelchair Transportation Safety

STATE OF THE SCIENCE WHITE PAPER ON WHEELCHAIR TRANSPORTATION SAFETY

Gina Bertocci, PhD and Douglas Hobson, PhD

Background/Introduction

In 1990, the U.S. Congress enacted the Americans with Disabilities Act (ADA) prohibiting discrimination against people with disabilities in employment practices, public accommodations and telecommunication services[1]. Transportation services, by legislative definition, fall within the public accommodation category. Therefore, public and private transportation service providers must accommodate persons seated in their wheelchairs who wish to travel. More recently, the 2001 New Freedom Initiative has cited integration of persons with disabilities in the workforce and the community as a priority, specifically noting 'transportation' as a critical factor in meeting this priority[2]. In support of the Initiative, the Director of Project Action reinforced this need indicating that one third of the 25 million transit-dependent people with disabilities report inadequate transportation as a significant barrier to integration. Such governmental priorities will continue to escalate the numbers of wheelchair users seeking transportation.

Wheelchair users who are unable to transfer to a motor vehicle seat during transport must rely upon their wheelchair to function as a vehicle seat. Unfortunately, design characteristics that make a wheelchair suitable for mobility often are in direct conflict with characteristics that define an acceptable motor vehicle seat. Typically wheelchairs are intended to serve as a "mobility aid", while motor vehicle seats are designed to secure their restrained passenger or driver to the motor vehicle, which in turn provides mobility. Motor vehicle seats also incorporate numerous design features that protect an occupant in a crash and, accordingly, extensive research has been dedicated to the design and development of vehicle seats[3-10]. Motor vehicle seats must also meet stringent government Federal Motor Vehicle Safety Standards[11]. Unfortunately, only limited effort has been devoted to-date to the research, development and design of wheelchairs and their seating systems intended to serve as vehicle seats.

The past decade has, however, seen a flurry of activity related to wheelchair transportation standards development. Voluntary industry standards that address both wheelchair securement in motor vehicles and wheelchairs used for transport on motor vehicles have been developed and adopted both nationally and internationally. One of the leading test facilities in the United States—at the University of Michigan Transportation Research Institute (UMTRI)—reports that over 73 manual wheelchairs, 27 power wheelchairs and 16 securement systems were frontal impact tested last year in accordance with either SAE or ANSI/RESNA Standards[12]. Clearly manufacturers have embraced the standards and have taken measures to begin offering transport-safe products. Development and compliance with these standards represents the critical first steps towards increasing the safety of those traveling seated in their wheelchairs. However, despite the tremendous effort that has been made toward industry standards, much work remains to be done in order to bring the safety of persons traveling in wheelchairs to a level equivalent to the safety of persons traveling seated in motor vehicle seats.

Review of the Science

Standards

Hobson recently compiled a summary of wheelchair transportation standards[13]. The development of wheelchair transportation standards, both nationally and internationally, has been divided into two major categories: (1) wheelchair securement and occupant restraint, and, (2) wheelchair crashworthiness. Wheelchair securement and occupant restraint systems are addressed in the United States through the Society of Automotive Engineers (SAE) J2249 Wheelchair Tiedown and Occupant Restraint Systems (WTORS) Standard and internationally through the International Standards Organization (ISO) 10542 Wheelchair Tiedowns and Occupant Restraints Standard[14-16]. Both of these standards define design requirements, instructions to users and test requirements for WTORS. As a part of compliance with these standards, WTORS must be able to secure an 85 kg (187 lb) surrogate wheelchair and restrain a 50th percentile male test dummy during a 20g/48kph frontal impact test event. Test criteria consist of maintaining WTORS integrity and meeting limitations of wheelchair and occupant excursion.

The second category of wheelchair transportation standards, wheelchair crashworthiness, is addressed nationally through the ANSI/RESNA WC-19 Wheelchairs Used as Motor Vehicle Seats Standard, and internationally through the ISO 7176/19 Wheelchairs Used as Motor Vehicle Seats Standard[17,18]. These standards, which focus on the use of a wheelchair as a motor vehicle seat, propose design requirements, instructions to users and test procedures for wheelchairs intended for transportation. A significant design requirement established by these standards is the addition of four securement points on transport-safe wheelchairs which are compatible with end fittings of strap

type tiedown securement systems. This requirement was defined in response to difficulty in properly identifying locations on the wheelchair for attachment of tiedowns. Frontal sled impact testing is perhaps the most stringent of tests to be conducted for compliance with ANSI/RESNA WC-19 and ISO 7176/19. This testing subjects an appropriately sized wheelchair-seated test dummy to a 20g/48kph frontal impact sled test. In the ANSI/RESNA WC-19 test protocol, the wheelchair is secured and the occupant is restrained using a surrogate WTORS. (The ISO 7176/19-DIS test protocol permits wheelchair securement and occupant restraint using a commercial WTORS.) ANSI/RESNA WC-19 and ISO 7176/19 test criteria assess wheelchair integrity, as well as occupant and wheelchair kinematics.

Despite an effort by ANSI/RESNA WC-19 and ISO 7176/19 to evaluate wheelchair crashworthiness, the addition of often used after-market or optional wheelchair seating systems will invalidate wheelchair testing. Consequently, wheelchairs utilizing after-market seating systems may not be sled tested to evaluate their ability to withstand crash level forces. Additionally, replacement seating systems provided in the field which differ from those provided with a WC-19 or ISO 7176/19 approved wheelchair will invalidate compliance and will not have been tested. Therefore, methods to evaluate a wheelchair seating system's crashworthiness, independent of the numerous different wheelchair frames that it may be coupled with in the field, are desirable. Towards this end, both international (ISO) and national (ANSI/RESNA) standards groups have organized efforts to address after-market transport-safe wheelchair seating. The ISO 16480 and ANSI/RESNA Seating Devices for Use in Motor Vehicles working groups have recently begun work on this standard. Both of these groups have agreed to pursue development of independent dynamic seating test methods.

Research in Transport-Safe Wheelchairs and Wheelchair Seating

Early wheelchair transportation research primarily focused on efforts needed to advance standards development. These early studies worked toward the development of a repeatable frontal impact test using a re-usable surrogate wheelchair[19]. As a part of the standards effort a computer simulation model was used to investigate the effects of wheelchair tiedown system characteristics, crash pulse corridor, and seated posture on tiedown and belt loading, wheelchair excursions, and occupant crash response[20]. Although most injury research and prevention fields are driven by epidemiology-based studies detailing accident statistics, only limited data on accidents involving persons using wheelchairs as seats in motor vehicle crashes is available[21-24]. A number of studies have also attempted to investigate the injury risk associated with using a wheelchair as a motor vehicle seat, investigating the effects of crash pulse[20], securement point location[20,25], restraint configuration[26-28] and seated posture[20].

Supporting the fact that wheelchairs are not typically designed to sustain crash-level forces, component testing studies have shown that casters, seat attachment hardware and seat support surfaces often fail at loads similar to those imposed in a frontal impact crash[29-32]. Unfortunately, design criteria to guide manufacturers in the development of transport-safe wheelchairs and wheelchair seating systems are relatively scarce. Information that exists in the literature has been largely been derived from computer simulation of frontal impact events[28,33,34]. These studies have shown that numerous factors (e.g. rear wheelchair securement location, seat stiffness, seat angle) can influence loads that wheelchairs are exposed to in a crash. These findings suggest that manufacturer design decisions can greatly impact the crashworthiness of wheelchairs. While performance of all wheelchair components is key to occupant crash protection, seat design and integrity are of particular concern since vehicle seat characteristics and failure have been linked directly to injury risk in motor vehicle crashes[3-10]. Frontal impact sled tests (20g/48kph) of commercial wheelchairs have shown seating system failures to be relatively common[12]. Seat attachment hardware, seat support surfaces and seat backs (on rebound) are among the most common components to fail under frontal impact conditions.

Previous studies which have attempted to elucidate wheelchair seat loading under crash conditions have consisted of both computer simulation studies and limited sled testing. Computer simulation studies have shown that frontal impact seat forces are dependent upon crash pulse, rear securement point location, seat characteristics and restraint configuration[20,28,33,34]. A limited series of frontal impact sled tests conducted by Gu and Roy with disc-type load cells incorporated into the ISO surrogate wheelchair and using a Hybrid III 50th percentile male test dummy measured seat loads[28]. Shaw also estimated seat loading in frontal impact sled testing using pressure sensitive film placed on the seat and load cells located beneath the front wheels of commercial manual wheelchairs with various types of seating systems (i.e. sling, rigid foam mounted on plywood)[35]. In these tests Shaw estimated vertical seat loads and found that higher loads were associated with the more rigid seating systems. Recent frontal impact testing (four tests) conducted by Bertocci and Manary using the SAE surrogate wheelchair evaluated seat loads using disc-type load cells incorporated into the wheelchair seat and also evaluated the effects

of rear securement point location[36]. This recent series of sled tests provided validation to a previously conducted computer simulation study[33].

While these studies provide a first approximation of wheelchair seat loading under 20g frontal impact conditions, limitations exist. Experimental measurement techniques used in sled tests conducted by Shaw were limited since seat loads were estimated from measurements recorded at only the front wheels and did not account for that portion of the seat load which may be distributed over the rear wheels. Gu and Roy's testing utilized measurement techniques directly assessing seat loads, but unfortunately only one sled test was conducted at the 21g/48kph level; all others were below this crash severity. Recent frontal impact tests conducted by Bertocci and Manary are also somewhat limited and can be used only as a guide since they utilize the SAE surrogate wheelchair which is more rigid than a commercial wheelchair.

While these previous studies represent a preliminary effort towards development of transport-safe wheelchairs and wheelchair seating, additional efforts are needed to advance safe wheelchair transportation. Testing and computer simulations to-date were conducted with a 50th percentile male test dummy; no studies have been conducted to evaluate seating loads associated with child-sized test dummies. Furthermore, previous studies evaluated seat loading in frontal impact conditions alone; no efforts have been undertaken to study seat loading under rear and side impact which are likely to impose very different loading conditions. Despite observed failure of seat backs during the rebound phase of frontal impact testing, no efforts have been mounted to evaluated seat back loading conditions. Wheelchair seat backs are also subjected to unique loading conditions in rear impact crashes, yet no studies have been conducted to quantify seat back or wheelchair loading in rear impact. More detailed investigative studies, such as those conducted in the automotive industry, are also needed to evaluate the effects of wheelchair seating design on injury risk. Clearly additional guidance is needed to provide wheelchair manufacturers with guidance related to seating system design for transport-safe wheelchairs. Also, research to-date has been conducted by a very limited number of re-searchers and academic institutions, in order for the field of wheelchair transportation to advance, academic training is clearly needed to promote more diverse research efforts.

Future Work as Identified by Standards Committee

With completion of ANSI/ RESNA WC19 Wheelchairs Used as Seats in Motor Vehicles, the Subcommittee on Wheelchair and Transportation has identified the following additional work items. These items, in priority order include: (1) completion of a companion document to provide the rationale for provisions within the standard, along with useful information for manufacturers, consumers and clinicians (2) independent testing for after-market seating systems, (3) crashworthiness of wheelchairs secured by other than four-point tiedowns, (4) universal docking interface, (5) harmonization with ISO and CSA, (6) restraint of small children, (7) rear impact crashworthiness, (8) design criteria for secondary supports and surfaces, and (9) side impact crashworthiness. Most of these items have also been cited as priorities within the ISO Standards committees.

Summary Points

- Wheelchairs and their seating systems are key to providing adequate protection to wheelchair users in a crash.
- Voluntary industry standards have provided the first critical steps toward improved wheelchair user crash protection.
- Voluntary industry wheelchair transportation standards provide test methods, design guidelines, labeling and instructions to users.
- Education of consumers, clinicians and manufacturers is key to effective standards implementation.
- As compared to the motor vehicle industry, little research has been conducted related to the effects of wheelchair and wheelchair seating design on occupant protection and injury risk.
- Additional design guidelines are needed for wheelchair and seating manufacturers to develop and provide consumers with transport-safe products.
- Preliminary guidelines for wheelchair seating (not including the seat back) have been developed using computer simulation and limited sled impact testing.
- Test methods to evaluate wheelchair seating independent of a specific wheelchair frame are needed.
- Rear and side impact wheelchair and seat loading conditions have not been consider thus far. Standards groups have also defined additional work items that include addressing side and rear impact.
- No efforts have been made to quantify impact seat loading associated with children. Transport-safe wheelchair seating design criteria (frontal, rear and side impact) is needed for pediatric wheelchairs.
- Additional researchers and research training are needed to advance the wheelchair transportation field.

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Seating for Postural Control

STATE OF THE SCIENCE WHITE PAPER ON SEATING FOR POSTURAL CONTROL

Elaine Trefler and Mark Schmeler

Introduction

Seating for persons with physical disabilities often entails consideration of posture, comfort and pressure management. Depending on the person's diagnosis and life goals, the priorities of his or her personalized seating goals will vary. This paper addresses issues related to providing persons with disabilities wheelchair seating that is primarily concerned with attaining a functional posture in the presence of considerable abnormal tone. Tonal abnormalities, high or low, that offer challenges for the seating specialist are often the result of an insult to the central nervous system (CNS) in persons such as those with a diagnosis of cerebral palsy, closed head injury, or diseases that affect the CNS.

Spasticity management can include issues related to neurophysiological techniques, primitive postural reflexes, abnormal movement patterns, proximal stability, orientation in space, sensory and visual disturbances, and discomfort (Herman & Lange, 1999). Whatever the major source of the abnormal tone, the challenge is to provide seating systems that normalize tone as much as possible, prevent, delay or accommodate the deformity that often accompanies tonal disturbances that persist over time and, finally, to position the person in a posture in which they can attain maximal independence and function (Trefler, 1993).

People who have tonal problems and who require a wheelchair as their primary means of mobility/seating, experience unique postural problems. The damage to the brain can occur in diffuse or specific patterns and to any portion of the brain. Therefore, the patterns of tonal dysfunction will vary with every individual. Patterns of velocity, gradation of movement, patterns of movement, resistance to passive stretch, control of muscle grading and coordination, and predictability of movements are all issues of tonal malfunction (Byarm, 1996).

The presence of abnormal pathology and reflexes requires that intervention first normalize the tone before a functional posture can be attained. However, factors such as sensory input, environmental factors (temperature, noise), primitive postural reactions, and general positioning in space can all have an affect on muscle tone (Nwaobi, 1987, 1986). High extensor tone can thrust people out of their normal seated posture. Asymmetrical tone often results in postures that deviate from the midline. Full body tone can be initiated by the person's own changes in posture, by a noise in the environment, or by any number of body or environmental stimuli. Postures that are dominated by abnormal tone can affect upper extremity function (Reid, 1996).

The tone that results from a central nervous system dysfunction affects the body as a whole. Therefore intervention must address the posture as a whole, all limbs, trunk, head and their position in space as well as their position relative to each other. Another consideration is that persons with central nervous system dysfunction often experience secondary complications. Cognitive deficiencies, the inability to communicate verbally, seizure disorders, personality changes and/or sensory abnormalities may add to the complexity of the problem of working with this population to attain a functional posture.

State of the Science

The state of the science of postural seating is still in the clinical realm. There are very few publications that are peer reviewed and provide a body of evidence-based practice (Roxborough, 1995), (Green, Nelham, 1991), (Poutney, Green, Mulcahy, Nelhan, 1999), (Poutney, Mulcahy, Clarke, Green, 2000). Most documented practices are in the form of magazine case studies, book chapters containing mainly the clinical practices of the authors, and conference papers again presenting best practice strategies of the authors (Bergen, 1985) (Cook & Hussey, (1995), (Cooper, 1997), (Presperin, 1990), (Taylor, 1997). The publications are excellent and the authors have years of experience solving problems related to posture and tone as related to seating and wheeled mobility systems. However, third party payers, consumers, and newly graduated professionals are now asking for documentation that proves that any intervention proposed will work and that it will work better than other options available. In summary, there is little outcome data to justify the technology, the service or the cost of seating intervention.

A survey of peer-reviewed publications related to wheelchair seating showed that studies in posture and spasticity/tone deal almost exclusively with the use of medication/drugs in tone management (Fitzgerald, 2001). In contrast with this, clinical practice in seating mobility focuses on postural control in tone management. This disparity of focus between published research and practice arises because no quantitative methods or tools exist that can be used to measure outcome in wheelchair seating intervention; the possible exception would be the use of seat pressure mapping tools, which is still controversial in clinical decision making and usually of little relevance for persons with intact sensation.

Seated posture and function are largely determined qualitatively through observation, using different evaluative methods in each clinical site. There are several clinical measures of functional performance that have been used in clinical research. However, the methodology has not been rigorously tested for validity and reliability and these measures look at wheelchair related function and not specifically at seating/posture (Axelson, 1997; Axelson and Chesney, 1996). Rudimentary attempts at quantification of the seated position in the wheelchair have been done using terms of mild, moderate and severe as a qualitative measure of orthopedic deformity and neuromotor involvement (Trefler, 1978). However, these measures, although useful for communicating the general status of a client, are not accurate enough to record small changes in status or changes over time. They cannot provide sufficient information for informed decision-making, provide a basis for and consolidation of evidence-based practice, or quantify outcomes in support of third party expenditures. This is particularly the case when the time span between evaluations is long or the evaluator has changed. Documented methods of defining levels of ability based on postural abilities have been validated and are available for use in practice (Poutney, Cheek, Green, Mulcahy, Nelham, 1999), (Green, Mulchaney, Poutney, 1995). Even the terminology used in the field of seating is not yet standardized either for body motions or parts or for seating technology components. Fortunately, this is being rectified as part of the ANSI/RESNA/ISO Seating Standards work.

Evidence-based practice is becoming increasingly important as clinicians are presented with an expanding range of treatment options, as health care funding is decreasing and the need for accountability is rising, and as health service consumers are taking more control of their own health (Roxborough & Sollazzo, 1998). At one time therapists were interpreting client needs to technical staff for custom fabrication. Now, however, there is considerable choice in the seating technology marketplace. The challenge is to assist consumers and assistive technology practitioners (ATP) and suppliers (ATS) to choose wisely from a multitude of products, many of which are marketed as having the same function. There is little research available related to the decision-making process of measuring clinical results in the application of seating and mobility technology (Minkel, 1998).

Service Delivery Issues

Service delivery generally consists of the technology that is available and used in solving the seating needs of persons with disabilities and the service system through which these same people must navigate in order to be evaluated for technology and get it funded and fit. First of all, there are some issues related to the technology. Due to fluctuations in the user's tone and condition, most systems must be adjustable in a simple and timely manner. Adjustments may need to occur across prolonged periods of time or on a daily basis as the user's needs fluctuate. Adjustments need to be easy to perform but at the same time must hold their adjustments against considerable force. Currently, most readily available components such as tilt-in-space, reclining back, elevating legrests, and adjustable height armrests are all wheelchair components. There are few positioning components that are easily adjustable (Reid, Rigby, 1996). Other adjustments generally require the use of tools and some customized assembly of the system. Some of these adjustments also require the use of power components and a power wheelchair if they are to be accomplished by the user. Finally, we do not have many dynamic seating/wheelchair components that move with the person during episodes of high tone and return to a resting position. Perhaps this is related to not having the evidence that dynamic components are effective in managing high tone as it relates to posture.

Durability of components is also a concern in the clinical setting. High tone places a significant amount of stress on various components of the system leading to breakage and the need for repeated and major repairs, often not covered by payers. Back-up wheelchairs are not covered due to duplication of service. The user is then left without a functional system, affecting their ability to attend work or other necessary activities while looking for funding for repairs. This is especially the case with back supports and footrest assemblies. There is existing technology on the market to address these issues but it is frequently unknown to clinicians. Also, these components do not have codes in the current funding system (HCPCS). Major funding justification is often required for coverage to occur and this process is very time-consuming for the clinician and complicated for the consumer. The current HCPCS coding system only addresses this through the use of Heavy Duty and Extra Heavy Duty wheelchair codes (K0006 and K0007) which tend to focus more on the weight of the user rather than the need for durable adjustable and modular components for users with increased tone.

Service delivery issues range from standards of practice and clinician expertise to billable technology and services. Standards of practice related to the application of seating technology, especially for people with abnormal tone and fluctuating needs, is limited to anecdotal textbook type information. They are not an issue to the experienced clinician or those who might take the opportunity to research problems in the literature or access listserves for guidance.

However, they do become an issue with the average clinician who is expected to apply seating concepts in their routine areas of practice. The clinician who is a generalist does not see the volume of seating clients that necessitates learning appropriate technology application. They often rely on applying what is available, fundable, codeable or easily documented by the HCFA (Health Care Finance Administration). If a generalist clinician were to follow the HCFA wheelchair criteria for people with increased extensor tone, they would provide their clients with a reclining back wheelchair; however, in many cases, it is clinically contraindicated for people with this condition.

Standards that address terminology of seating components or possible configurations that might be tried or simulated prior to prescription do not exist. ISO/RESNA working groups are now working on some seating standards. Seating simulators are vital tools that can assist the clinician in conducting postural trials. Unfortunately, this aspect of the clinical process is rarely available to the generalist clinician due to high cost and the fact that these clinicians haven't experienced the value of a simulator. Simulation and clinical trial needs to be made a standard of practice in this field and a documented requirement by funding sources especially for HCFA. Simulation is especially important for a population in which several degrees of tilt or a small change of head position in space can alter total posture rendering a person non-functional.

Clinicians are currently under considerable pressure to bill for every moment of their time in today's health care environment. The time required to conduct a thorough seating assessment is not respected by many funding sources. It is expected that a generalist OT or PT evaluation should take no more than one hour. Often, complicated seating evaluations for people with increased and fluctuating tone well exceeds the magical hour. Wheelchair seating and mobility assessments need their own HCPCS code and need to be considered on a continuous time basis rather than on a one-time assessment basis.

Finally, the existing HCFA infrastructure for coding and funding seating technology is antiquated, discriminatory, and often not within sound clinical practice, especially as it relates to people with multiple and complex needs. HCFA policies are often adopted by State Medicaid programs and private payers. A prime example is HCFA's indicator for a reclining back wheelchair for a person who has increased extensor tone of the trunk. In most cases, a reclining back would be contraindicated for this condition because it would actually increase abnormal tone. There is no code for tilt-in-space seating. Tilt-in-space components are also being questioned by many payers as to whether they are medically necessary. The therapeutic benefit of a tilt-in-space system to a person with high tone is that their posture can be incrementally adjusted until the effects of gravity are minimized. There is also no mention of the need for gravitational postural realignment to prevent collapsing deformities of the spine within the HCFA coding system. Little empirical data to show that tilt-in-space helps to reduce tone and provide relaxation is available. The current major justification for tilt-in-space is mostly related to pressure relief and the prevention of pressure sores. Further research needs to be conducted to justify the need for tilt-in-space technology especially as it relates to people with advanced seating needs associated with tone and collapsing deformities.

Community/User Issues

Persons with high tone often have multiple challenges, which may include an inability to communicate verbally. This one disability makes it very difficult, if not impossible, for them to be their own advocate. Parents, teachers, spouses and other multiple caregivers often need to be involved in the clinical service delivery process. Multiple needs, multiple caregivers, multiple environments all add to the complexity of problem solving. In a service delivery system that tries to be consumer responsive, it is very challenging to involve consumers with high tone in decision making related to their own technology. It is even more challenging involving them in the research that will add knowledge and technological design to assist in advancing the field of specialized seating for their particular needs.

Summary of the Current State of Seating for Postural Control

Clinical Status and Issues

- The service delivery system, and funders in particular, do not recognize the complexity of providing seating to people with advanced needs.
- There is no incentive for clinicians to conduct thorough assessments for people with high tone and complex needs. Current funding practices do not reimburse therapists for sufficient evaluation time. Reimbursement for training in the use of the technology is not common practice.
- There is no reimbursement for 24-hour positioning programs or technology.
- There is a need for standardized methods of clinical postural measures. They would assist the clinician in documenting changes in deformity, function and posture over time. This, in turn, would assist in the prediction of technology choices over time and realistic long term planning.
- Few seating/wheelchair components on the market today can survive without breakage for persons with high tone. Because of the frequency and strength of extensor thrust, especially in but

not limited to an adult population, parts must be extremely strong and anchor points reinforced. Also, for persons with CHI, sometimes their tone changes rapidly over the first several years post injury. Systems need to be easily adjustable to accommodate the changing posture.

- Persons with high tone are of all ages and have various functional needs. Components that transfer from manual to powered chairs, or even furniture, with ease and safety would be helpful.
- Clinicians and researchers do not understand the effects of dynamic components and their effects on spasticity. However, more dynamic possibilities are becoming available on the market. As we better understand the effects of dynamic components, more appropriate options will follow.
- Asymmetry often demands aggressive midline positioners; these need to be securely mounted so as not to move when the person experiences high tone episodes and yet are removable or swing away for transfers or management. Unfortunately, components and seating practices are often at odds with each other.
- People with abnormal tone have multiple needs, such as access to controls for powered chairs, AAC devices, ECU's, and so forth. They must have enough stability provided by their seating system to support limited motor control in order to operate multiple or integrated controls systems.

Research Status and Issues

- There is little evidence-based practice addressing seating/mobility concepts for persons who experience abnormal tone.
- Standardized measures of posture and function while seated would assist both clinicians and researchers in developing outcome measures.
- Documentation of the importance of 24-hour positioning that includes a wheelchair seating component is not readily available although positioning in the lying position is one component of posture (Green, Mulcahy, Poutney, 1995).
- Evaluation tools such as simulators would assist the clinician with effective evaluations of seating needs.
- Outcome measures to compare effectiveness, and cost effectiveness, of seating interventions are needed.
- Research is required to better understand the frequency, force and natural history of episodes of high tone.
- There is a need for a better under-standing of how posture affects function.
- A definition of "good" posture and how it impacts function is needed. It will provide the field with a better understanding of the effects of seating intervention on such issues as the progression of postural deformity, swallowing, respiration, digestion, and cardiopulmonary status.

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Wheelchair Seating Comfort

STATE OF THE SCIENCE WHITE PAPER ON WHEELCHAIR SEATING COMFORT

Douglas Hobson and Barbara Crane

Introduction

Historically, due to the high costs associated with decubitus ulcers, research effort in wheelchair seating has focused on seating technology for static pressure management (Cooper et al., 1997). This work has focused largely on redistribution of buttock loading through specialized cushion technology and, more recently, by alteration of seated posture by self-actuated adjustments to the seat support surfaces. However, powered tilt-in-space and back recline wheelchair seats, developed mainly for use by persons with high level spinal cord injury, most often place a person in a non-functional position when the dynamic feature is used. Another population that has received significant R&D focus has been children with neuro-motor impairments that result in their inability to use standard wheelchair seats (Hobson, 1990). As the following literature review will show, comparatively little investigation has been directed towards the population of wheelchair users who have normal or near-normal sensation, and are debilitated by their inability to achieve adequate relief from sitting discomfort and, in some cases, pain.

For able-bodied persons, relief from discomfort during routine sitting is accomplished through small, unconscious body movements or postural adjustments that maintain discomfort at tolerable levels. For persons with advanced stages of Multiple Sclerosis (MS), Muscular Dystrophy (MD), Amyotrophic Lateral Sclerosis (ALS), in addition to some people with Post Polio Syndrome (PPS), the discomfort and pain of daily wheelchair sitting can be a chronic problem. Due to their neuromuscular disorder, they are often unable to adjust their body position to attain adequate redistribution of supporting forces. In addition to the potential for decubitus ulcer formation, many people in this population experience intolerable periods of discomfort, which can lead to reduced participation in daily activities including work, education and recreation.

State of the Science

Many individuals with disabilities have identified seat discomfort as a major issue or problem with their wheelchairs (Bardsley, 1984; Monette, Weiss-Lambrou, & Dansereau, 1999; Shaw, 1992; Shaw & Taylor, 1991). The negative effect of seat discomfort on function has been identified among individuals in skilled nursing facilities (Herzberg, 1993).

In 1995, a national needs survey was conducted by the RERC on Technology Transfer, targeting 700 assistive technology consumers, many of whom were wheelchair users. Comfort was indicated as one of the leading unmet needs in the area of seating design requirements (Scherer, 1996). In a recent study of ALS patients, wheelchair features noted to enhance comfort were among the most desirable features of both manual and power wheelchairs (Trail, Nelson, Van, Appel, & Lai, 2001). These features included high back supports, head and neck supports, and supportive arm rests. These features all enhance the support and comfort of wheelchair users. Weiss-Lambrou et al. used the QUEST consumer satisfaction measurement tool to evaluate 24 wheelchair users with a mean age of 47 years. From a list of 19 variables measured, comfort was chosen to be the most important variable (Weiss-Lambrou, Trembly, Lacoste, LeBlanc, & Dansereau, 1998). A study with a group of elderly subjects under the mentoring of this project's task leader is the only reference found which specifically targets the discomfort needs of the elderly population (Shaw, 1992).

In another area of disability, a study was done that compared self-adjustments made by transtibial amputees using a powered alignment device to adjustments deemed ideal by a highly quailfied professional. The results suggest that self-adjustments are more effective at achieving desired comfort (Hobson, 1972). This principle may also be applicable to dynamic seating for discomfort relief.

There are several challenges in the research of seating comfort. First, there is no general agreement on the meaning of comfort and discomfort. Several authors have suggested various meanings (Barkla, 1964; Branton, 1969; Fubini, 1997; Helander & Zhang, 1997; Lee, Schneider, Reed, Saito & Kakishima, 1991; Shackel, Chidsey, & Shipley, 1969; Shen & Vertiz, 1997;

Zhang, Helander, & Drury, 1996).

There have been two studies – one on office workers (Helander & Zhang, 1997) and one on individuals who use wheelchairs (Monette et al., 1999). These two studies have emphasized a multi-factorial nature of comfort and discomfort and identify possible factors that are characteristics of each.

Discomfort factors noted among office workers included: sore muscles, heavy legs, uneven pressure, stiffness, restlessness, fatigue, and pain (Helander & Zhang, 1997). Comfort features identified in this same study included relaxation, refreshed feelings, spaciousness of the chair, liking the chair, and aesthetic appearance of the chair. Monette, et al. found similarities among individuals who used wheelchairs. They identified comfort features such as feeling good, feeling supported in the right places, feeling little pressure under the buttocks, feeling stable, feeling satisfied, and several others. Their discomfort factors included such things as having pain, feeling the need to move, feeling unstable, feeling physically tired, feeling a burning sensation, sliding out of the wheelchair, feeling stiff, and several others (Monette et al., 1999). This research has been helpful in the development of an assessment tool that may help people rate levels of comfort and discomfort in their seating systems.

Possibly the most significant advances to date have been made in the human factors area of office chair design. Several seat characteristics were found to be of importance in providing overall comfort. These included material stiffness and texture, friction properties (Fubini, 1997), dynamic properties such as spring-assisted or power-assisted seat adjustment mechanisms (Jones, 1969; Shen & Vertiz, 1997), and aesthetic design, plushness, and softness (Helander & Zhang, 1997). These same characteristics have not been well-studied in populations of individuals with disabilities.

There is general agreement that comfort is a highly complex concept and is somehow reliant on several properties of seats and backs including: friction properties of the materials used, thermal regulation properties, softness or firmness of the surfaces, and adjustability of the surfaces (Lee et al., 1991; Shen & Vertiz, 1997). There is also some agreement that short-term comfort needs and long duration sitting comfort needs are most likely very different (Helander & Zhang, 1997; Lee et al., 1991). Many of these concepts have not been studied in the populations of individuals with disabilities who spend a majority of their waking hours in wheelchair seats. This is especially true of individuals who have motor impairments with very little sensory impairment.

In industry, manufacturers of office, automotive, and truck seats have done extensive product development to enhance seat comfort and user productivity for the able-bodied population. All of these innovations are based on the premise that normal seated comfort is not derived from a single static posture, but requires changes in posture (dynamic seating) over time. For example, ergonomic office furniture has long utilized spring loaded seating components, such as pivoted lumbar supports, seat back recline, and seat tilt, that are just now being researched to accommodate changing extensor muscle tone of wheelchair users (Ault, Girardi, & Henry, 1997; Evans & Nelson, 1996; Orpwood, 1996). However, the spring-loaded movement of wheelchair seating and the body-powered office ergonomic seating approaches are unlikely to be appropriate for the movement requirements of the target disability population.

Since much of the work is targeted at product development for contract office seating, the research process remains proprietary or unpublished. The results of the work are seen in the work of Don Chadwick and Bill Stumpf for the Hemann Miller Corporation chairs called “EQUA” and “AERON.”

Automotive seating developments have taken a different approach. Most modern car seats are designed to safely support a driver and promote comfort by facilitating small posture shifts in a compliant bucket seat. Powered seat position and shape adjustments are used to facilitate customization by different drivers so that both small and large drivers can comfortably control the vehicle. Once an “optimal” seat configuration is achieved using manual or power controls, it is presumed that the driver will maintain it for prolonged periods – using body power to make minor postural adjustments in the statically compliant seat for comfort during driving. One premium car seat manufacturer, Recaro, has started marketing their “race car” seats with power tilt and recline and lumber cushion to wheelchair users.

Automotive seating has also begun incorporating load sensing electronics into the seat pans. The sensors “read” how much the driver weighs and roughly maps the distribution of their mass. While this currently aids the process of “smart” airbag deployment, patents exist for

using this load data for the purpose of automatic surface compliance control directed at user comfort.

Unlike most car seats, which are designed for only a few hours of continuous use per day, truck seating is designed for much longer use cycles. Long haul truck drivers will spend 10 or more hours per day in their seats, six days per week. Many independent truckers substantially exceed these limits. It is not surprising that truck seats are more highly adjustable than car seats, and that power adjustments on premium seats actively facilitate postural repositioning of the seated driver in more ways than car seats. In addition to power backrest recline and lumbar form, seat pan tilts and extension, an aftermarket high-end operators seat will have electro-pneumatic control over seating surface compliance. It will also have under and side buttock bladders, and up to six independent lumbar/sacral bladders allowing operator control over the form of this area. Heaters, massagers, power positionable armrests, and memory units that store user settings are available as options. The typical cost of these units is $1,000-$2,000.

In summary, a great deal of research has been done in various ways to assess discomfort with relatively little agreement among researchers on how this should best be done. For example, several researchers have attempted to find an objective correlate with a person's subjective rating of seating discomfort (Branton, 1969; Cohen, 1998; Fenety, Putnam, & Walker, 2000; Lee & Ferraiuolo, 1993; Shaw, 1993). In spite of these efforts, there has been little success in linking feelings of discomfort with quantitative indicators such as seat interface pressure, EMG indicated muscle fatigue, or observed posture. There has been particular interest in linking interface pressure with discomfort, but to date there have been no conclusive studies (Gyi & Porter, 1999). This lack of an identified objective measurement tool has frustrated many of the researchers in this field. Several subjective measures of comfort and discomfort have been developed and used in studies of office furniture, general use furniture, and wheelchairs (Helander & Zhang, 1997; Jones, 1969; Monette et al., 1999; Shackel et al., 1969). Many of the studies have used more than one of these tools in order to improve the reliability and validity of the outcomes.

Service Delivery Issues

The populations most affected by seating discomfort issues are those with primarily motor impairments with little or no sensory involvement. Many are long duration sitters who have little opportunity to move in and out of their seating systems throughout the day. These include individuals with MS, adults with MD, individuals who have had Polio and/or Post Polio Syndrome, those with incomplete spinal cord injuries, and those with late stage ALS. This can also include those with severe arthritis or other musculoskeletal disorders who are also limited in mobility.

These individuals often use wheelchairs for mobility for 12 hours or longer on a daily basis. The focus of service delivery with these individuals is often on function and the need for mobility. Little attention is paid to their seating support systems unless there is a direct impact on functional abilities. Because of their relatively low risk for developing ischemic ulcers, they sometimes are not even provided with pressure relieving seating components. Many of these individuals' comfort needs are not addressed at all clinically until they are so severe as to limit function. Comfort is not usually considered a legitimate need, even by many clinicians.

Other service delivery issues are related to funding of technology. One of the major reasons that clinicians do not see comfort as a legitimate medical need is that funders do not see it as a medical necessity. Comfort must always be related back to a functional or physiological problem in order to be considered as a reason for requiring equipment. In addition to the lack of funding availability for comfort related products, there is lack of evidence of effective comfort enhancing products on the market. Clinicians must use a "trial and error" method of finding appropriate equipment or modifying existing equipment. This is a costly process and is poorly supported by current funding structures.

Due to the lack of funding availability and the clinical bias against legitimacy of discomfort as a problem, there has been little research and development into comfort related products. Manufacturers have not been challenged to meet this need because of the lack of the service delivery process to drive this research and development.

Comfort problems can and do lead to individuals retreating to bed for much of the day. This leads to impaired function, poor quality of life, and medical problems such as pneumonia, bed induced ischemic ulcers, and overall withdrawal from life's activities.

Community/User issues

From a community viewpoint, a lack of comfort can have a dramatic impact on the social role performance of individuals with disabilities. Discomfort can have a negative impact on work and school performance. This in turn may limit the productivity of individuals with disabilities, further stigmatizing them as "unable to work or be productive members of society". This stigma can have a very negative effect on what roles may be considered appropriate for wheelchairs users. Such a stereotype will ultimately have a cost associated with it for individuals who use wheelchairs and for the community as a whole.

Wheelchair users themselves will also have several issues related to discomfort. The clinical bias around the legitimacy of comfort needs may cause users themselves to believe that this is not an important issue. This belief may create an inner conflict and make people feel that they must deny their comfort needs or be viewed in a negative light. They also face a frustration of either having to live with severe discomfort or retreat to a non-functional state (such as to bed). Neither of these options is particularly enticing. The lack of availability of equipment or funding resources combined with clinical and societal bias leaves them with very few solutions. The only solutions available are often function limiting. These include the use of tilting or reclining systems. These systems were not designed for relief of discomfort, nor were they designed with function in mind. They are an inadequate solution to a complex problem.

Summary of Current Status of the Field

- Historically, relatively little research effort has focused on disability and seat discomfort.
- Seat discomfort has been identified as a priority in a number of studies. The population of wheelchair users most in need is that group of persons with near normal sensation but with a lack of sufficient motor function to relieve discomfort (MS, ALS, MD and post-polio).
- Current wheelchair technology designed mainly for pressure relief of high level spinal cord injured does not adequately meet the needs of this target population.
- Extensive research and development effort has been done in support of office and automotive seat products. Many of the findings of these commercial successes have not been applied to wheelchair seating.
- There seems to be little agreement amongst ergonomists or disability researchers as to how best to quantify discomfort or produce tools that can reliably link feelings of discomfort with qualitative indicators, such as surface interface pressure.
- There does appear to be agreement that the sensation of discomfort is complex and multi-factorial in nature.
- The need for comfort in the target population is not considered a legitimate clinical need and therefore is not funded by most third party payers. Consequently, products with discomfort-relief features have not become routinely available.
- Discomfort problems lead to reduced participation in the activities of daily life by the target population.

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Session Notes and Priorities

RESEARCH AND DEVELOPMENT PRIORITIES FOR TISSUE INTEGRITY MANAGEMENT IN WHEELCHAIR SEATING

The following items are the research and development priorities identified by the 18 members of the Tissue Integrity Management panels. The panels' decisions regarding the importance of each item are noted in parentheses.

- To investigate the etiology of pressure ulcers. (Important, not urgent)
- To develop and validate multi-factorial models to address mechanical, metabolic, and physiological considerations. These models need to address our basic understanding of the etiology of pressure ulcers and be directed toward development of measurement tools for assessing changes in clinical practice. (Important and urgent)
- To investigate the effects of forces on soft tissue and how these forces are mediated by physiological, metabolic and clinical factors. (Consensus that this is included in 2nd bullet item.)
- To further develop and refine tools to predict level of risk. (Urgent!)
- To use the understanding of pressure ulcer etiology to improve the design of wheelchair seat cushions. (Urgent! 9-8)
- To develop standards which support the clinicians' needs for decision-making and enable developers to meet the needs of users and clinicians. (Urgent! 16-2)
- To develop and disseminate research methodologies to test cushion efficacy. (Remove from list, 16-2)
- To investigate clinical factors such as compliance, follow-up and re-evaluation interims, and activity relative to their effects on pressure ulcers. (Keep on list, all in favor; Urgent, 10-8)
- To investigate the effects of seating system components and configurations on tissue integrity management. (Keep on list, 11-0)
- Epidemiology of pressure ulcer incidence attributable to wheelchair seating.

WHEELCHAIR TRANSPORTATION SAFETY GRAND SUMMARY

A. Research

Do rear and side impact present unique wheelchair seating design challenges?
How can we best describe the epidemiological aspects of wheelchair transportation?

- Wheelchair Seating for Side Impact __0__
  - Head restraint, back support design aspects related to Side Impact
  - Postural/occupant restraint harnesses Issues Related to Side Impact
- Wheelchair Seating for Rear Impact __11__
  - Seat back design related to Rear Impact
- Vehicle Compartment (WC Securement Station) Design Issues Related to Side Impact (side air bags, etc.) __0__
- Epidemiological Studies (Accident and Wheelchair Transportation Distribution/Usage/Cost of Injury Studies) __33__
- Identify Barriers to Transportation/Needs Assessment __21__
- In-Depth Crash Analysis (effects of standards and injury risk) __11__

B. Service Delivery

How do insurance companies and third-party payers view the “transit option” wheelchair?
What are the industry barriers to preventing development and marketing of transport-safe seating products?

- Epidemiological Based Studies __20__
- Increased number of Transport-Safe Products __2__
- Increased Compatibility Across Various Manufacturer’s Products __15__
- Guideline Documents and/or Education for Clinicians/RTS/Consumers (such as vehicle operators, etc) __14__
- Standards for Transport-Safe Wheelchair Seating __7__
- Disclosure of Performance on Standards by Manufacturers __2__
- Limiting the Additional Cost of Transport-Option Seating __3__
- Addressing Liability Issues Related To Transport-Safe Products __3__

C. Standards

Of what should the priorities of the newly formed *Seating Devices for Use in Motor Vehicles* standards groups consist?
If an independent seating system test is developed, what does this mean in terms of the complete wheelchair system (i.e. wheelchair frame and seating system) compliance with standards?

- Development of Independent Seating System Test Method(s) __27__
- Working Towards Manufacturer’s Acceptance on Approach to Resolve Liability Concern in Independent Seat Testing (mating of frame and seating components) __6__
- Addressing Special Needs Groups (e.g. custom molded seating systems, larger occupants) __7__
- Develop Guidelines for Traveling with Seat Back Reclined (e.g. use of recline and tilt-in-space seating systems) __5__
- Addressing Stability of WC-Seat Interface when Driving __7__
- Limiting Cost of Independent Seating System Testing __9__
- Guideline Documents to Educate on Standards __10__

D. Education/Capacity Building

What are the most effective means to educate consumers, clinicians and manufacturers on wheelchair transportation standards and safety issues?
How can research interest in wheelchair transportation be increased?

- Develop Internet-Based Education and Training Sites __9__
- Develop Paper-Based Education — Consumer Magazines, Professional Journals __5__
- Educate via Consumer Group Meetings __2__
- Development of Video-Based Education and Training Tools __0__
- Continuing Education for Clinicians __21__
- Needs Assessment/Epidemiological Studies — critical for funding agencies __27__
- Lobbying — convincing political leaders that integration of people with disabilities will benefit the community __*__
- Corporate attitudes — convincing businesses that integration of people with disabilities into workforce will benefit the company __*__

  *****16 votes in favor of combining bullets 7 & 8 into one comprehensive advocacy/public policy statement.
- Develop Informative Guidelines for whether or not to Transfer to a Vehicle Seat (discussion regarding individuals traveling in motor vehicles in their w/c) __1__

POTENTIAL DISCUSSION QUESTIONS FOR WHEELCHAIR TRANSPORTATION SAFETY

- What are the most effective means to educate consumers, clinicians and manufacturers on wheelchair transportation standards and safety issues?
- How can research interest in wheelchair transportation be increased?
- How do insurance companies and third-party payers view the “transit option” wheelchair?
- What are the industry barriers to preventing development and marketing of transport-safe seating products?
- Do rear and side impact present unique wheelchair seating design challenges?
- Of what should the priorities of the newly formed *Seating Devices for Use in Motor Vehicles* standards groups consist?
- If an independent seating system test is developed, what does this mean in terms of the complete wheelchair system (i.e. wheelchair frame and seating system) compliance with standards?
- Will there be a need for an independent wheelchair frame test?
- Will manufacturers accept such an approach?
- What are the liability issues related to this topic?

STATE OF THE SCIENCE WORKSHOP FOLLOW-UP RANKING OF SEATING FOR POSTURAL CONTROL ACTION STATEMENTS

Chair: Elaine Trefler
G-5 Moderator: Dan Lipka; G-6 Moderator: Jessica Pedersen

A. Research

A1. What is the nature of postural control?

Preamble Summary

- Changeable/fluctuating
- Complex
- Outcomes of abnormal tone on posture and function are unproven
- Biomechanical conflict between stability vs. mobility
- Postural control has not been quantified and/or information effectively disseminated
- Guidelines of postural abilities exist but are not universally known
- Natural history of deformity management is unknown. Issues include seating, orthotic principles, etc. Are they compatible with function?
- Need to establish parameters of posture/function/deformity as they relate to the seated posture
- Need a vocabulary and tools to do this
- Function not symmetry or posture should be the measure of a positive outcome
- Define the interaction between an active and a passive posture
- Clinical standards of practice need validation and dissemination
- Postural readiness a prerequisite for function
- Role of comfort in posture
- Does postural control require a dynamic component?

Ranked A1 Action Statements

A.1.1 Investigate the dynamic components of posture and their influence on readiness (4.14).
A.1.2 Investigate and quantify facets of postural control. (3.71)
A.1.3 Develop a definition of the ready posture. (3.62)
A.1.4 Investigate the natural history of deformity and document its relevance to posture. (3.05)

A2. What is the definition of a ready posture?

Preamble Summary

- Individual (personal)
- Measures of outcomes need to be reliable and repeatable and based on validated standards of practice.
- Components of posture need tools to assist in defining and measuring them (function, comfort, readiness, physiological).
- Do standards of practice insure better outcomes? If one includes elements of a standard of practice (mat evaluation, simulation, etc?), are outcomes more favorable?
- Outcome tools that are specific to posture are not available.
- What is the standard definition of a ready posture? (eg. neutral, functional, symmetrical)

Ranked A2 Action Statements

A.2.1 Document and validate standards of practice. (4.19)
A.2.2 Define what is meant by a ready posture in measurable qualities (include quality of life and global components or posture). (3.95)
A.2.3 Develop tools and methods to measure the ready posture. (3.95)

B. Development/Service Delivery

B1. What is best practice?

Preamble Summary

- Compare outcomes in clinics that maintain the standard of practice and those that don't.
- Document the effects of 24 hour postural management programs
- Clinical needs need to drive research priorities, not policy or funding
- Understand postural goals
- Seating technology development should follow clinical postural goals. Dynamic components are one possible intervention
- Does postural control require a dynamic component?
- Randomized clinical trials needed to validate best practice
- Ethics of research are a concern if some clients do not receive best practice
- Documentation of predictors of deformity
- Standard documentation in order to contribute to best practice database
- Document cost benefits of seating as a component of intervention including surgery, therapy, pharmaceutical treatment, etc.
- Document risk management (function that results in deformity)

Ranked B1 Action Statements

B.1.1 Validate best practice. (4.05)
B.1.2 Define best practice. (4.00)
B.1.3 Develop standard practice parameters and develop a database for the field. (3.73)
B.1.4 Document predictors of deformity and develop cost benefit ratio. (3.64)
B.1.5 Define the role of dynamic postural components in best practice. (3.27)
B.1.6 Establish a clearinghouse of information. (3.18)

B2. Are there service delivery issues that need attention to ensure best practice?

Preamble Summary

Products

- Document best practice
- Standardize definitions of components that enable ready posture
- Focus on components' design features that enable the ready posture
- What postural components benefit from a dynamic component?
- What is the effect of a dynamic component on posture (tone)?
- What is the definition of a dynamic component (variable, active, adjustable, smart technology)?

Process

- Define best practice
- Document outcomes of best practice
- Document differences in service delivery and service delivery following a best practice
- Clinical research to validate best practice
- Specific measures of outcomes
- Consistent definitions of posture from both client and clinician perspective
- Develop consistent data collection methods
- Change from the focus on funding technology to funding the delivery process including evaluation, technology and follow-up
- Differentiate between postural restraint and postural facilitation. (Does one preclude the other?)
- Document compliance practices

Ranked B2 Action Statements

B.2.1 Document cost benefits of seating intervention (4.33)
B.2.2 Measure outcomes of best practice in multiple settings. (4.30)
B.2.3 Clarify functional posture from client and clinician perspective. (4.29)
B.2.4 Define and clarify best practice. (3.95)
B.2.5 Promote clinical trials. (3.95)

B3. Is there a need to develop products that could aid in the provision of a full range of appropriate technology for client use?

Preamble Summary

- Develop components based on clinical need
- Smart technology that facilitates self-operated components
- Measures of technology effectiveness (real life consumer reports)
- Tie abandonment literature to prescription process
- Tie assessment data to client/technology match
- Need to better understand the functional purpose of dynamic components and who they benefit
- Develop products for evaluation purposes

Ranked B3 Action Statements

B.3.1 Research the need for dynamic components and appropriate populations for use. (4.05)
B.3.2 Develop products that facilitate client evaluation. (3.82)
B.3.3 Develop a consumer report of product performance. (3.57)
B.3.4 Encourage manufacturers to develop smart technology that is client operated and based on clinical need. (3.48)

C. Standards

C1. Is there a need for unique standards in terminology, measurement and outcome information in the field of seating intervention for postural control?

Preamble Summary

- Standard terminology for such concepts as: position/posture, static/dynamic, postural readiness
- Document accepted vocabulary and measurement practices
- Outcome measures that consider clinical need/research need — tools may be different
- Match research data to clinical information

Ranked C1 Action Statements

C.1.1 Develop outcome measures that document the effectiveness of clinical process and technology effectiveness. (4.57)
C.1.2 Document evaluation and measurement practices (4.19)
C.1.3 Develop standard terminology to address clinical practice. (3.90)
C.1.4 Establish a data base for the field (3.33)

D. Capacity Building/Education

D1. What educational efforts should be developed and launched that can advance and support the inclusion of principles of seating for postural control into clinical practice?

Preamble Summary

- Education modules for all team members at all intervention levels
- Pre-service and continuing education
- ATP, ATS, Consumers and advocates, Payers
- Documentation of best methods
- Disseminate available materials
- Educate clinicians in research methods
- Promote clinical trials with reimbursement for clinical involvement (ATS, consumer reimbursement).
- Encourage retrospective research and then develop prospective studies based on results
- Teach features and benefits not products
- Promote use of media for education and communication
- Publish in both peer-reviewed and other publications for dissemination of information

Ranked D1 Action Statements

D.1.3 Facilitate publication of best practice and outcomes in multiple sources for multiple audiences. (4.43)
D.1.1 Promote the development of educational materials for all constituents. (4.05)
D.1.2 Investigate delivery methods for educational materials. (3.32)

WHEELCHAIR SEATING COMFORT GRAND SUMMARY

Chair: D. Hobson
Group 7 moderator: J. Herman; Group 8 moderator: S. Stadelmeier
(Ranked by 33-36 participants, 13 of whom submitted editorial comments.)

Definition of Seating Discomfort

Seating discomfort may be defined as: "A negative feeling, reaction or sensation, that usually occurs over time, that can often limit a person's ability to function in their mobility system and therefore their expected or desired role within society. It often first presents itself as an unconscious desire to change body posture. It is often associated with one or more factors such as: sitting instability, forward sliding, excessive heat build-up, stiffness, excessive localized soreness or pain, spasticity, or stretch. It may be specific in location or generalized, but diminishes when the person is able to initiate frequent changes of their seated posture or is no longer in the mobility device. It can be a precursor to the development of secondary conditions such as joint deterioration, ulcer formation, and circulatory disorders."

A. Research

A1. Is discomfort a problem of significant importance to warrant future research and development? (Core question to both groups)

G-7 Preamble summary

- Pain and discomfort are the precursor of breakdown; an ischemic event is what is causing the pain. The issue is controlling ischemia and the related consequences regardless of the seating issues and the level of disability. Seating has attempted to control this ischemia. If not controlled it results in ischemic pain.
- Fluid dynamics may also be significant in the process. Part of the problem is that it is very difficult to measure and track; but it is a very important subject.
- What is discomfort and what is pain? How do you measure something that is highly individual and very difficult to quantify?
- There are several topics involved — comfort, discomfort, pain, ischemia, chronic pain. These are different questions; many variables are involved.
- The perception of discomfort is made up of multiple factors, of which pain is only one part.
- The difficult part is to put all factors together and figure out what is primarily responsible for discomfort.
- Do we need to determine at what threshold an inability to tolerate discomfort requires withdrawal from the seating system?
- Are we talking about those who do not have the ability to shift their posture?
- Yes, we are limiting the focus to those people that can sense seating discomfort but are unable to relieve it in normal ways due to their static postures and reduced motor capacity.
- People come into the clinic because they are not comfortable in their chairs. This is often the primary complaint and it is difficult to deal with.
- A lot of people in wheelchairs do not complain of seat interface pain, but rather of low back pain and neck pain, possibly due to instability and the lack of normal curves in the lumbar and cervical spine. It is necessary to allow people to shift their position and not remain in the same position.
- Dennis Zacharkow talks about stability — stabilizing the skeletal system to relax the muscular system; this actually facilitates blood flow (and thereby controls ischemic pain).
- Pain that comes from being at end-ranges of motion — appears later on in the sitting process – if joints are not in mid-position; the stretch of joint structures can also cause pain.
- We need to know how to distinguish pain along a continuum. We also need better indicators of when pain is a symptom of a problem vs. indicative of a tolerance threshold.
- Is discomfort always an indicator of an underlying problem?
- When is the seating the problem and when are other issues primary and need to be addressed?

G-8 Preamble Summary

- Why is this topic just now being talked about?
- The people who are using seating and mobility devices are generally not paying for them, therefore they are not demanding comfort.
- Is this an attitude that treats comfort as a luxury and not as a necessity?
- In the traditional contract seating business, increased comfort was associated with luxury. The president, who is in the office once a week, got the comfortable chair, not the secretary who sat and typed everyday. This has been found to be an unproductive equation.
- Is chronic discomfort an issue? Sitting tolerance is how this gets talked about.
- How do we quantify it? Are functional systems comfortable systems? Is there a relationship between comfort and preservation of tissue integrity?
- No one says that comfort is not important. It should be defined.
- Can discomfort affect productivity and quality of life? Does this take away from its importance when you attach it to productivity and quality of life? The element of comfort is so subjective.
- Comfort is not decadence.
- Is discomfort related to pain or injury? This does not exist in the literature. We use discomfort (often) as an intermediate step in the progression to discussion of injury and pain. We do not know the relationship between (dis)comfort and the progression toward injury and pain.
- Consumers will make the case that (dis)comfort needs to be highly considered. We need to give them the tools to ask for consideration of (dis)comfort and measure it.
- If we think (dis)comfort is important, we shouldn't dance around it but clearly state it is important.
- How do you establish this kind of increase in comfort for people who are not verbal? Relaxation is associated with non-verbal signs occurring in the face and posture changes.
- Pressure mapping may be related to improving comfort. When pressures are managed the report is that increased comfort follows.
- When flying long distances, the venous return has become an issue with "economy class" syndrome. This leads to discomfort. Are there similar other kinds of physiological responses?
- There is more to (dis)comfort than just the seat you are sitting on. Thirst, air temperature, etc. are also important. When engrossed in a meaningful task, the awareness of discomfort is often suppressed, though it can be brought into the consciousness.
- Back to the discomfort, pain, and injury mechanism. This relationship is unknown. When the awareness of pain is present it may be too late.
- If you interviewed a group of consumers, they would say that "comfort is their main issue" and is at the top of their list. Now that other things are taken care of this has highest priority with them.
- What things influence (dis)comfort? What is (dis)comfort? How do you measure (dis)comfort?
- Are comfort and discomfort on the same continuum? Comfort = the relief from pain or anxiety. In the context of seating, how do you differentiate between the factors that influence (dis)comfort? There are secondary disabilities associated with immobility. If you do a negative thing long enough there will be damage.
- We need to know whether pain and discomfort is a problem and can we represent that in clear and effective ways so that it is clearly perceived as a problem.
- Do some epidemiological studies to determine its importance among consumers. Then engineering solutions could be built in to increase consumer control of discomfort.
- In Europe, there is a greater interest in comfort in power chairs. Chairs are more padded, powerful, i.e., the Barcalounger approach. Look at other places where people have taken a look at a similar issue. Using this idea, how have other industries dealt with this? Look at the sleep surface industry that has a lot of human factors research in the area of temperature, pressure and humidity control.
- Discomfort may also be related to the issue of control over the experience. The person who is experiencing discomfort needs to be respected and given the tools to change, manage or control the experience. Build in mechanisms that allow control over the posture, position, and pressure.

Ranked A1 Action Statements (G7 & G8)

A.1.1 Investigate the multiple physical and physiological factors that could potentially lead to seating discomfort. (3.92)

A.1.2 Develop tools and terminology that will permit wheelchair users to communicate their subjective feelings of discomfort. Include a high percentage of users in this development, not as objects of study, but as active participants in the process. (3.89)

A.1.3 Develop seating devices that give users increased control over their posture and the configuration of their support surfaces. (3.78)

A.1.4 Conduct epidemiological survey(s) that attempt to quantify the magnitude of the discomfort problem in the target population. (3.72)

A.1.5 Investigate how other industries (aircraft, auto, truck) are addressing the discomfort problems of long distance passengers or operators. (3.72)

A.1.6 Investigate discomfort as an indicator of an existing or pending health problem in contrast to a time-dependant tolerance reduction issue. (3.50)

A2. Is a clinical tool required that will quantify the seating discomfort of a wheelchair-seated person?

G7-Preamble Summary

- Yes, this would be great to have.
- Yes, I think a clinical tool or tools that will clinically quantify seating discomfort are required.
- Pain or discomfort is very subjective and difficult to quantify. The only existing method of quantifying sitting tolerance is asking how someone feels.
- I would like to see several tools that can be used in conjunction with each other.
- A tool like the Norton or Braden scales of risk for breakdown assessments that look at several areas would be useful.
- Quantitative tools are better than qualitative tools as they are much more scientific.
- Productivity is not necessarily a good indicator as people can work through a lot of discomfort and still be productive.
- A basic clinical tool – such as a basic survey of equipment use and abandonment.
- No clinical tools exist, which leaves us using open-ended questions for qualitative measurement.
- There is a similar problem in the prosthetics field, regarding pain and discomfort in residual limbs – component alignment is critical to minimize pain; often those decisions are made by clinicians, and then the amputees modify their gait to minimize discomfort. Do we need to put the person into the loop and allow the person to adjust their own support surfaces to minimize their discomfort? That is, use the person's own intact sensory system to determine what adjustments need to be made to the support surfaces to relieve discomfort.
- A tool that reflects their self-initiated adjustments in support and positioning.
- Adjustability is important in allowing someone to be comfortable.
- What the person perceives as absence of discomfort is what is really important.
- How do you calibrate comfort, even from day to day as the amount of comfort changes? Do you train people how to assess cushions? One researcher has found that the more you use subjects, the worse they get at assessing comfort.
- Is edema an important indicator of discomfort; is this a good physical correlate of a problem in the tissue that causes discomfort and pain?
- Edema, heat, redness, all may be physical correlates that help to clarify discomfort – regardless of what came first, the swelling or the pain.
- Pain scales often cause increases in pain.
- Heart rate and respiration are also affected; changing position to improve respiratory capacity often causes discomfort.
- Limiting function will cause discomfort and will not be tolerated.
- Function can often be more important than comfort.

- Tools should be as objective as possible, but also need to include subjective experience of discomfort.
- Tools should be sensitive to the fact that discomfort is a highly subjective and individual sensation; how do you compare from time to time or from person to perso?

Ranked A2 Action Statements (G-7)

A 2.1 Develop a tool that quantifies the affect of discomfort on sitting tolerance, function, etc. (3.84)
A 2.2 Develop a tool that correlates pain or discomfort with one or more physiological factors such as; edema, skin color, temperature, heat build-up, tissue loading, blood flow, etc. (3.57)
A 2.3 Develop a specialized discomfort scale, similar to the traditional VAS pain scales. (3.19)
A 2.4 Develop a tool that distinguishes central pain or intrinsic discomfort vs. discomfort caused by the seating system. (3.05)
A 2.5 Develop a tool to distinguish psychologically induced discomfort from physically induced discomfort. (2.54)

B. Development/Service Delivery

B1. What are the industry barriers (funding, attitude, awareness, product) preventing the development and marketing of wheelchair seating that address the holistic needs of wheelchair users with discomfort problems? (Core question to both groups)

G-7 Preamble Summary

- We get around these problems by not talking about discomfort and instead talking about postural support and function. However, a lot of our intervention is aimed at minimizing discomfort.
- People are not being honest about this topic because it is not a recognized need.
- Discomfort is not considered a “medical necessity”.
- Medical necessity is usually only considered that which lengthens life not that which makes it better or of higher quality; medical necessity does not fall into this category.
- Do we need to change our rationale for providing our seating intervention?
- Since this will never be considered a medical necessity, should we just continue with calling this pain and not discomfort?
- Maybe we should be providing seating for quality of life issues.
- There are a lot of products out there that consumers can buy for themselves, but these are not appropriate devices for the target population.
- The big market for discomfort-relieving products is the elderly and these folks will not usually purchase this for themselves.
- The inability to provide longer-term trials of equipment is a barrier to deciding what is truly suitable for discomfort.
- A big barrier is that the consumer does not feel that they have to pay for seating system – that it is the third party payers are responsibility and if the insurance won’t pay, they are not interested.
- Consumers do not value comfort or the positive outcomes of appropriate equipment.
- We live in a culture that values productivity but devalues people who complain about pain.
- Comfort is unique to each individual, therefore difficult to design products that will be comfortable for a wide range of people.

G-8 Preamble Summary

- In the UK, the voucher scheme allows you to use government money to purchase your wheelchair and to add more money to those resources to get the level of product that you need.
- In the UK, abandonment of traditional Health Service wheelchairs is as high as 50%. Discomfort was #3 on the list of reasons why a wheelchair was abandoned.
- The research and clinical community should provide leadership in responding to consumer need. The current third party funder response can be changed (as it was with pressure and posture) through this leadership.

- There is an element in the cultural values of older adults that pain is not something to be complained about.
- The health care system has kept the lid on expectations of consumers with the belief that the system will not pay for discomfort management. The strongest advocacy comes from the consumer.
- We need to provide the evidence and ask for it to be paid for. If consumer advocacy needs to be encouraged then we should help to sharpen and clarify this.
- If you make it clear to a funder that they are wasting money, then you have their interest. If you can relate "abandonment" to discomfort (as in the UK) you may have a funding angle?
- Research findings need to be translated into knowledge that influences clinical findings.
- Create an environment where systems change can take place.
- Consumers and clinicians have a stronger voice but they need knowledge (evidence) to move the practice forward.

Ranked B1 Action Statements

B.1.1 Conduct short-term clinical studies on discomfort-related issues such as: equipment abandonment, reduction of function, and impact on quality of life. (4.26)

B.1.2 Foster the availability of discomfort-relieving products that can be used for both short and long term user trials. (3.38)

B.1.3 Investigate means to have consumers assume more responsibility for obtaining equipment that is related to quality of life rather than medical necessity. (3.09)

B.1.4 Investigate the merits of changing the definition of medical necessity vs. finding alternatives to medical necessity. (3.00)

B.1.5 Foster the development and marketing of low cost discomfort-relieving consumer products rather than medically classified equipment. (2.89)

B.1.6 Collect anecdotal field evidence of supplier/user interactions surrounding comfort/discomfort aimed at determining scope and impact on supplier's effectiveness and user's satisfaction. (2.86)

B2. How much value do the people involved in prescribing/selecting seating systems (clinicians, vendors, caregivers, payor, the user himself) place in the "discomfortableness" of a seating system? (Group 7 only)

G-7 Preamble Summary

- I have found that clinicians do not value comfort enough.
- The opposite – clinicians have learned to "use the system" and thereby get comfort needs met for their clients.
- When we first learned specialized seating, we focused on postural support and did not design for comfort. This has changed now.
- Have the wheelchair seating industry manufacturers focused on designing for comfort? We don't see this, not because this is not valued, but because it is not consider in need within industry.
- Newer developments have been focused more on comfort ex: frog legs forks.
- Manufacturers have avoided comfort because payers don't value it.
- Payers don't focus on this; need more education of funding sources so they understand the importance.
- Caregivers and consumers need to be given permission to value comfort.
- The caregiver probably places the highest value on comfort.
- The consumer may value comfort, although tacitly, and needs to be given permission to openly request comfort.
- Clinicians value comfort highly but do not admit it openly or document it.
- Manufacturers may value comfort but don't label it or market it as such.
- The payor does not value it and needs to be educated as to the benefits.

Ranked B2 Action Statements

B.2.1 Conduct objective cost vs. benefit outcome studies that, if positive, can be used to educate third party payors as to the value of discomfort relieving products(4.20).

B.2.2 Foster a service environment in which caregivers and clients are encouraged to openly communicate their discomfort concerns and needs (4.06).

B.2.3 Encourage manufacturers to advertise the discomfort –relieving features of their seating products (2.89).

B.3 How is the level of discomfort determined by users, by clinicians, by product designers? (Group 8 only)

Preamble Summary

- Are comfort and discomfort on the same continuum? Comfort = the relief from pain or anxiety.
- In the context of seating how do you differentiate between the factors that influence comfort?
- By time it starts to hurt, we assume that some damage is being done. There is no data on this.
- If we believe that discomfort leads to pain and further to injury, then are we involved in injury prevention? Are we saying that if physical injury doesn't result then are we saying that only psychological damage is occurring?
- It's a multi-factorial issue. Feelings of loss of control, sliding, incorrect postural alignment can also contribute. Not just injury prevention. Anxiety and lack of control can be debilitating, too.
- There are lots of kinds of pain. One research question is to determine the kinds of pain there are.
- Develop a methodology to determine the factors that create discomfort. It is a multidimensional sensation.
- Are there existing objective measures that can be used? Diaphoresis, detection of anxiety (lie detector tests), breath responses, galvanic skin responses, etc.
- Cannot necessarily take a position that all discomfort is bad. It can stimulate you to move. It can be used to maintain or restore alertness.

Ranked B.3 Action Statements

B.3.1 Include a percentage of users in these investigations as team members, not simply as subjects of the study (4.26).

B.3.2 Conduct investigations to determine the relationship between seating discomfort and the onset of injury or other health-related problems (4.18).

B.3.3 Conduct investigations to identify the multi-factors that may lead to the sensation of sitting discomfort (4.00)

C. Standards

C1. Is there a unique role for seating standards development in the area of discomfort–related technology? (Core question asked to both groups.)

G-7 Preamble Summary

- This area cannot be addressed as a standard until we agree on a definition of discomfort and a way to assess discomfort, maybe after the next five years of looking at discomfort.
- It would be premature for a technical standard for discomfort products, but a standard of practice would be a valuable component of our assessment and intervention.
- A technical standard could provide test results that aid clinicians and consumers deciding what products may have the desired discomfort-relieving features.
- Technical standards do allow us to compare across products.
- A technical standard should describe features and properties and not comfort, which is dependent on the perception of the user.
- Design guidelines do exist for automotive seating in terms of how much foam to use between the person and any metal structure and what type of foam.
- Comfort assessment is definitely needed as a standard of practice and in practice guidelines.

G-8 Preamble Summary

- A standard of practice needs to be developed predicated on the current status of consumers in regards to discomfort. This will serve to identify the missing pieces and flaws in the science and best guide future research.
- To date, standards have been mainly technical test methods. This is good but may not be effective on this topic. It may be more important to first develop standards of practice. Is this a professional issue? Yes. These are different from technical issues.
- We are new at this. There are not products designed to address discomfort. Let the standards of practice guidelines be used to guide the development of products. This could also focus and drive the future research agenda.
- Rather than emphasize products we should know more about what we should do from the clinical practice viewpoint.
- Standards of practice may be the most effective way to implement change related to discomfort. However, before you can write a standard you have to have a way to measure it and quantify it.
- Give guidance without sanction. It is enough to create a roadmap.
- The NICE project has as its goal to improve clinical practice in hip replacement care in UK. Provide evidence that you are employing better clinical practices to reduce costs, improve satisfaction.
- When you outline where there is lack of evidence then you point exactly to the long and short-term research that is missing. For example, what is the effect of tilt in space in increasing someone's sitting tolerance?
- We don't have standards of practice that are evidence based that are easily accessible and usable by clinicians.

Ranked C1 Action Statements

C.1.1 Introduce technical guidelines (working drafts) early as provisional technical standards in order to raise awareness and enhance discussions between clinical practice, users, and manufacturers (4.18).

C.1.2 Develop a standard of practice guideline based on the current status of best practice in regards to discomfort. This will serve to identify the missing knowledge, clinical evidence and technology gaps and thereby best guide future research and development activities (4.18).

C.1.3 Develop a industry technical standard for seating discomfort products (4.00)

D. Capacity Building/Education

D1. What educational efforts should be developed and launched that can advance and support the inclusion of comfort principles into clinical practice (funding agencies, products, etc.?) (G-7 only)

G-7 Preamble Summary

- A task force for going to state Medicaid agencies and having them sit on cushions and really feel what comfort vs. discomfort is and what it feels like.
- Intervene with funding decision makers, focus on one particular area of seating and have people experience the device. The hard part is finding the person to talk to or to set up in-service training.
- The funding agencies need to be approached by independent sources rather than by manufacturers because of concerns about conflict of interest.
- Accessing the consumer can be done through other agencies – well-elderly centers.
- We have not done a good job at all at educating the funding agencies because we do not have outcomes or any evidence to back up what we say.
- We can access consumers through agencies such as MS society, ALS association, MD association, and through the State Tech Act projects.
- We need to start accumulating data and using it to back up what we are doing – need the research to validate what we are doing.
- We need to market the value of comfort to all areas, lobbying and task forces to educate consumers, funders.

- Need to get out of the paradigm of medical necessity.
- What about encouraging manufacturers to identify comfort features and market comfort features?
- This can be dangerous because it will cause denials of equipment just because they are marketed this way.
- Office furniture has made this move in their industry, as has automotive industry.
- Some of the newer products that are designed for comfort are being marketed to consumers and this is working.
- There are things that we can learn from the office chair environment.
- It may not be a bad idea for manufacturers to talk about comfort as a secondary to the main feature of the product. Example – webbed belt versus padded pelvic belts to provide stability and comfort.
- Do clinicians need education about this issue? Yes and no
- The ALS society in Georgia has been very good and proactive at working on quality of life issues.

Ranked D1 Action Statements

D.1 1 Develop awareness and educational programs for funding agencies, policy makers wheelchair users and the general public regarding the importance of discomfort problems, and fostering the view that lack of discomfort is a right and not a luxury. (4.30).

D.1 2 Develop professional education programs that will emphasize assessment of discomfort needs and the principles and language necessary for its documentation. (3.88)

D.1 3 Foster stronger feedback loops to manufacturers from clinicians and consumers regarding discomfort needs. (3.46).

D.2 How can prescribers/funders be influenced to change their thinking and base beliefs about discomfort and therefore the selection/purchase decisions of seating for others? (G-8 only)

Preamble Summary

- Give them evidence, as this is the key for policy and payment decisions.
- If researchers can give clinicians the information to change the practice then this will change the demand for funding.
- Research evidence is showing that shoulders wear out in manual wheelchair users. This is changing clinical practice when the cost of rotator cuff injury is contrasted with a $5000 power wheelchair.
- Put the evidence out in a proactive way. Not just put the data out and see who picks up on it.
- Paternalistic attitudes and low expectations among clinicians is a more difficult issue. The case may need to be made for appealing to “values” not “evidence.” Challenge these (existing) attitudes by empowering consumers.
- There was a recollection of the supplier who complained that a consumer was wearing out their wheelchair by using it too much.
- Standards of practice have not necessarily evolved with the development of products. The practice doesn’t necessarily start with the consumer and what they need.
- Post professional training is the area where the knowledge and practice develop.
- There is not enough time in professional education.
- The clinicians are now searching for tools and are trying to deal with the demand for evidence to drive their clinical practice. If we could give them tools we could support them and give consumers the best result.
- PKC Company in Vermont has created a diagnostic tool. It uses a computer to help interpret the meaning of symptoms and taps into a database of clinical evidence. It uses that data to help arrive at preliminary diagnosis.
- Continuing education is driven by regulation, certification, largely motivated by professional development and personal and professional motivation.
- Perhaps we need to organize sessions in public and professional forums to raise the awareness of this issue among clinicians. Get them to look at the issue with a different set of eyes.

- We should learn from past mistake, that is, not including the person with the disability in the discussion. We need to better understand the issue of discomfort in wheelchair sitting. What kind of (user) control is effective in changing the perception of discomfort?
- There is no person with a disability in this discussion. Perhaps this is something that should be addressed when we get back to Pittsburgh.

Ranked D2 Action Statements

D.2.1 Include a high percentage of users in the development of any educational materials related to comfort/discomfort. (4.15)

D.2.2 Investigate methods by which evidence-based information related to wheelchair sitting discomfort can be made readily available to clinicians, consumers and funders. (3.86)

Appendix A: Session Topics

AGENDA OF PLENARY AND BREAKOUT SESSIONS

FIRST PLENARY SESSION

Welcome; Explanation of the State of the Science Program; Distribution of Assignments; Introduction of Speakers
Presenter: C. Brubaker

Core Presentation: "The State of Knowledge and Practice for Tissue Integrity Management"
Presenter: D. Brienza

Core Presentation: "The State of Knowledge and Practice of Wheelchair Transportation Safety"
Presenter: G. Bertocci

CONCURRENT BREAKOUT SESSIONS

Tissue Integrity Management

Chair: D. Brienza

Group 1

Moderator: M. Ferguson-Pell

Recorder (easel): D. Brown

Recorder (laptop): K. Frost

Panel Members: S. Sprigle, B. Graebe, T. Krouskop, J. Herman, S. Johnson-Taylor, D. Lipka, M. Schmeler, G. Weisman

Group 2

Moderator: S. Margolis

Recorder (easel): L. Cohen

Recorder (laptop): B. Crane

Panel Members: T. Hetzel, J. Minkel, G. Taylor, A. Bergen, K. Koch-Hurst, S. Buck, J. Pedersen, A. Kieschnik

Wheelchair Transportation Safety

Chair: G. Bertocci

Group 3

Moderator: L. Schneider

Recorder (easel): VTC

Recorder (laptop): M.E. Buning

Panel Members: D. Hobson, B. Cotzin, F. Davis, D. Koester, S. Pierce, J. Padgitt, R. Nelham, T. Pountney

Group 4

Moderator: G. Bertocci

Recorder (easel): VTC

Recorder (laptop): A. Koontz

Panel Members: R. Cooper, S. Lindquist, S. Stadelmeier, G. Bardsley, S. Fitzgerald, S. Shutrump, J. Takacs, E. Stait, L. Wallace

SECOND PLENARY SESSION

Tissue Integrity Management

Report of Group 1 Breakout Session
Report of Group 2 Breakout Session
Section Chair Summary with Discussion (D. Brienza)

Wheelchair Transportation Safety

Report of Group 3 Breakout Session
Report of Group 4 Breakout Session
Section Chair Summary with Discussion (G. Bertocci)

THIRD PLENARY SESSION

Introduction of Speakers
Presenter: R. Cooper

Core Presentation: "The State of Knowledge and Practice for Postural Control"
Presenter: E. Trefler

Core Presentation: "The State of Knowledge and Practice for Seating Comfort"
Presenter: D. Hobson

CONCURRENT BREAKOUT SESSIONS

Postural Control
Co-Chairs: E. Trefler and M. Schmeler

Group 5
Moderator: D. Lipka
Recorder (easel): A. Koontz
Recorder (laptop): L. Cohen
Panel Members: G. Bardsley, S. Buck, S. Fitzgerald, W.B. Mick, S. Johnson-Taylor, R. Nelham, T. Roesler, S. Shutrump, S. Lindquist

Group 6
Moderator: J. Pederson
Recorder (easel): D. Brown
Recorder (laptop): K. Frost
Panel Members: T. Pountney, A. Bergen, B. Cotzin, L. Schneider, G. Taylor, S. Margolis, E. Stait, L. Wallace

Seating Comfort
Chair: D. Hobson

Group 7
Moderator: J. Herman
Recorder (easel): VTC
Recorder (laptop): B. Crane
Panel Members: R. Cooper, B. Graebe, K. Koch-Hurst, D. Koester, J. Padgitt, A. Kieschnik

Group 8
Moderator: S. Stadelmeier
Recorder (easel): VTC
Recorder (laptop): M.E. Buning
Panel Members: G. Weisman, T. Hetzel, S. Sprigle, J. Minkel, T. Krouskop, S. Pierce, J. Takacs, F. Davis

FOURTH PLENARY SESSION

Postural Control
Report of Group 5 Breakout Session
Report of Group 6 Breakout Session
Section Chair Summary with Discussion (M. Schmeler)

Seating Comfort
Report of Group 7 Breakout Session
Report of Group 8 Breakout Session
Section Chair Summary with Discussion (D. Hobson)

FIFTH PLENARY SESSION

Summary of Status and Recommendations for All Areas
Plenary Discussion
Prioritization for All Areas
Consensus Determinations
Recommendations for Future Research and Development and Training Agendas (Chair: C. Brubaker)

Appendix B: List of Speakers & Participants

RERC on Wheeled Mobility at the University of Pittsburgh

State of the Science Conference on Wheelchair Seating

February 19-20, 2001

Speakers and Participants

Geoff Bardsley
Tayside Orthopaedic
Dundee, Scotland
United Kingdom
researcher

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Valhalla, New York
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Dalthea Brown
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Clifford Brubaker
Professor and Dean
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Canada
Occupational Therapy

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Pittsburgh, Pennsylvania
student

Barbara Crane
University of Pittsburgh
Pittsburgh, Pennsylvania
student

Laura Cohen
University of Pittsburgh
Pittsburgh, Pennsylvania
student

Bette Cotzin
Physical Therapist
Washtenaw Intermediate School District
Ann Arbor, Michigan

Foster Davis
Freedom Designs
Simi Valley, California
manufacturer

Martin Ferguson-Pell
Chair
Disability and Technology
University College of London
Stanmore
United Kingdom

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University of Pittsburgh
Pittsburgh, Pennsylvania

Karen Frost
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University of Pittsburgh
Pittsburgh, Pennsylvania
student

Bob Graebe
Roho, Inc.
Bellville, Illinois
manufacturer

Janice Herman
NeuroBiology Institute
Scottsdale, Arizona
Physical Therapy

Thomas Hetzel
Littleton, Colorado
Physical Therapy

Douglas Hobson
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University of Pittsburgh
Pittsburgh, Pennsylvania

Susan Johnson-Taylor
Vernon Hills, Illinois
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Anne Kieschnik
ATS, CRTS
Seating Profiles
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Kay Koch-Hurst
Atlanta, Georgia
Occupational Therapy

Dan Koester
Ann Arbor, Michigan
researcher

Alicia Koontz
University of Pittsburgh
Pittsburgh, Pennsylvania
student

Thomas Krouskop
TIRR-REC
Houston, Texas
researcher

Steve Lindquist
Senior Project Engineering
Sunrise Medical
Longmont, Colorado

Dan Lipka
Miller's Assistive Technology
Akron, Ohio
Occupational Therapy

Simon Margolis
National Seating and Mobility, Inc.
Plymouth, Minnesota
researcher

W.B. Mick
Director
MED's National Rehabilitation Network
Boise, Idaho

Jean Minkel
Minkel Consulting
New Windsor, New York
Physical Therapy

Roy Nelham
Consultant Clinical Engineer & Director, Rehabilitation Engineering
Chailey Heritage Clinical Services
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United Kingdom

Joan Padgitt
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Physical Therapy

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Adaptive Mobility Services
Orlando, Florida
manufacturer

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Roho, Inc.
Belleville, Illinois
clinician

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Pittsburgh, Pennsylvania

Lawrence Schneider
Transportation Research Institute
University of Michigan
Ann Arbor, Michigan
research scientist

Sue Shutrump
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Stephen Sprigle
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Lisa Wallace
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consumer

Gerald Weisman
Director
Dept. of Rehabilitation Engineering
Randolph Center
Vermont

Appendix C: List of Acronyms

ACRONYMS

AAC	augmentative & alternative communication device
ADA	Americans with Disabilities Act
AHCPR	Agency for Health Care Policy and Research, U.S. Department of Health and Human Services
ALS	Amyotrophic Lateral Sclerosis
ANSI	American National Standards Institute
AT	assistive technology
ATP	assistive technology practitioners
ATS	assistive technology suppliers
CHI	closed head injury
CNS	central nervous system
DOT	Department of Transportation
ECU	environmental control unit
FDA	Food and Drug Administration
HCFA	Health Care Finance Administration
HCPCS	Center for Medicare & Medicaid Services (formerly Health Care Finance Administration) Common Procedure Coding System
ISO	International Standards Organization
MD	Muscular Dystrophy
MS	Multiple Sclerosis
NHTSA	National Highway Traffic Safety Administration
NIDRR	National Institute on Disability and Rehabilitation Research
NIH	National Institutes of Health
NRA	National Rehabilitation Association
OEMs	original equipment manufacturers
PPS	Post Polio Syndrome
R&D	research and development
RERC	Rehabilitation Engineering Research Center
RESNA	Rehabilitation Engineering and Assistive Technology Association of North America
SAE	Society of Automotive Engineers
UMTRI	University of Michigan Transportation Research Institute
WC or W/C	wheelchair
WORS	wheelchair occupant restraint system
WTORS	wheelchair tiedown and occupant restraint systems