State of the Science White Paper
On
Wheelchair Seating Comfort
by
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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 places a person in a non-functional position when the dynamic feature is used. Another population that has received the 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.

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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). Weiss-Lambrou et al. used the QUEST consumer satisfaction measurement tool to evaluate 24 wheelchair users with a mean age of 47 years. From the list of 19 variables measured, comfort was listed 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 comparative study of transtibial amputees, that were allowed to self-adjust their prosthetic alignment using a powered alignment device, was compared to adjustments deemed ideal by a highly qualified professional The results suggests 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, plush-ness, 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 this work is targeted at the product development of contract office seating, the research process remains proprietary or unpublished. The results of the work is 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 already started marketing their "race car" seats with power tilt and recline and lumber cushion to wheelchair users.

Automotive seating has also begun the incorporation of load sensing electronics into the seatpans. 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 exsist 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 per day of continuous use, truck seating is designed for much longer use cycles. Long haul truck drivers will spend 10 or more hours per day in their seats, 6 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. An aftermarket high-end operators seat in addition to power backrest recline and lumbar form, seat pan tilts and extension, will have electo-pneumatic control over seating surface compliance. It will also have under and side buttock bladders, and up to six independant 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. 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 this 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, is the 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 obvious 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 may limit the productivity of individuals with disabilities, further stigmatizing them as "unable to work or be productive members of society". This can have a very negative effect on what roles may be considered appropriate for individuals who use wheelchairs. This 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 will create an inner conflict and may make people feel that they must deny their comfort needs or they will 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 are those 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 is therefore not funded by most third party payers. Therefore 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

References

Ault, H. K., Girardi, M. M., & Henry, C. T. (1997, June 20 -24). *Design of a dynamic seating system for clients with extensor spasms.* Paper presented at the RESNA Proceedings.

Bardsley, G. I. (1984). The Dundee seating programme. *Physiotherapy, 70*(2), 59-63.

Barkla, D. M. (1964). Chair angles, duration of sitting, and comfort ratings. *Ergonomics, 7*, 297-304.

Branton, P. (1969). Behaviour, body mechanics and discomfort. *Ergonomics, 12*(2), 316-327.

Cohen, D. (1998). An objective measure of seat comfort. *Aviation Space Environmental Medicine, 69*(4), 410 - 414.

Cooper, R., Gonzalez, J., Lawrence, B., Renschler, A., Boninger, M., & VanSickle, D. (1997). Performance of selected lightweight wheelchairs on ANSI/RESNA tests. *Archives of Physical Medicine and Rehabilitation, 78*(10), 1138-1144.

Evans, M., & Nelson, W. (1996, June 7). *A two position seat to back interface.* Paper presented at the Annual RESNA Conference, Salt Lake City, UT.

Fenety, P. A., Putnam, C., & Walker, J. M. (2000). In-chair movement: validity, reliability and implications for measuring sitting discomfort. *Applied Ergonomics, 31*, 383-393.

Fubini, E. (1997). The interaction between technical requirements and comfort in car seating. *Collections of Anthropology, 21*(2), 405-427.

Helander, M. G., & Zhang, L. (1997). Field studies of comfort and discomfort in sitting. *Ergonomics, 40*(9), 895-915.

Herzberg, S. (1993). Positioning the nursing home resident: an issue of quality of life. *American Journal of Occupational Therapy, 47*(1), 75-77.

Hobson, D. (1972). A powered aid for aligning the lower limb modular prosthesis. *Bull. of Prosth. Res.* (fall), 10-18.

Hobson, D. A. (1990). Seating and mobility for the severely disabled. In R. Smith & J. Leslie (Eds.), *Advances in Rehabilitation Engineering* (pp. 193-252). Boca Raton, Fla: CRC Press.

Jones, J. C. (1969). Methods and results of seating research. *Ergonomics, 12*(2), 171 - 181.
Lee, J., & Ferraiuolo, P. (1993). Seat comfort. *Seat System Comfort and Safety, SAE special publication, 93/963*, 1-5.
Lee, N. S., Schneider, L. W., Reed, M. P., Saito, M., & Kakishima, Y. (1991). An investigation of driver discomfort and related seat design factors in extended-duration driving. *SAE 1991 Transactions- Journal of Passenger Cars Section 6*, 130 - 159.
Monette, M., Weiss-Lambrou, R., & Dansereau, J. (1999). *In search of a better understanding of wheelchair sitting comfort and discomfort.* Paper presented at the RESNA Annual conference.
Orpwood, R. (1996). *A compliant seating system for a child with extensor spasms.* Paper presented at the 16th RESNA Annual Conference, Salt Lake City, Utah.
Scherer, M. J. (1996). Users desires for wheelchairs. *Rehab Management*, 121-123.
Shackel, B., Chidsey, K. D., & Shipley, P. (1969). The assessment of chair comfort. *Ergonomics, 12*(2), 269-306.
Shaw, C. G. (1993). Seat cushion comparison for nursing home wheelchair users. *Assistive Technology, 5*(2), 92-105.
Shaw, G. (1992). Wheelchair seat comfort for the institutionalized elderly. *Assistive Technology, 3*(1), 11 - 23.
Shaw, G., & Taylor, S. (1991). A survey of wheelchair seating problems of the institutionalized elderly. *Assistive Technology, 3*, 5-10.
Shen, W., & Vertiz, A. (1997). Redefining seat comfort. *SAE Transactions, Journal of Passenger Cars, 6*(1), 1066-1073.
Weiss-Lambrou, R., Trembly, C., Lacoste, M., LeBlanc, R., & Dansereau, J. (1998, June 26 - 30). *Consumer criteria for evaluating satisfaction with wheelchair seating aids: Quest results.* Paper presented at the RESNA, Minneapolis, MN.
Zhang, L., Helander, M., & Drury, C. (1996). Identifying factors of comfort and discomfort in sitting. *Human Factors, 38*(3), 377-389.