DEVELOPMENT AND VALIDATION OF THE WHEELCHAIR SEATING DISCOMFORT ASSESSMENT TOOL (WcS-DAT)

by

Barbara Anne Crane

BS, University of Connecticut, 1989

MA, Saint Joseph College, 1997

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This dissertation was presented

by

Barbara Anne Crane

It was defended on

January 14, 2004

and approved by

Douglas A. Hobson, Ph.D.

Margo B. Holm, Ph.D., OTR/L,
FAOTA, ABDA

Steve Stadelmeier, M.Sc.

Matthew P. Reed, Ph.D.

Rory A. Cooper, Ph.D
Dissertation Director

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Barbara Anne Crane, PhD, PT

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Wheelchair seating discomfort is an important but poorly understood negative outcome for long duration wheelchair users. A major impediment to the study of this problem is the lack of a validated tool for quantification of wheelchair seating discomfort. The goal of this dissertation research was to develop and validate an assessment tool appropriate for the quantification of wheelchair seating discomfort among long duration (> 8 hours per day) wheelchair users. This was accomplished through the completion of three research phases, each described within the body of this dissertation. Phase I consisted of a qualitative research study involving in-depth interviews with experienced wheelchair users. Data from these interviews resulted in the development of the Wheelchair Seating Discomfort Assessment Tool (WcS-DAT), a three-part tool to allow wheelchair users to quantify their level of seating discomfort. Phase II of the research assessed the reliability and concurrent validity of this assessment tool through a test/re-test reliability study. Intra class correlation (ICC) coefficient scores ranged from 0.83 to 0.97, indicating adequate reliability of the two discomfort scores in the WcS-DAT. Internal item consistency, assessed using Cronbach's alpha, indicated that all items were consistent and not redundant, with scores ranging from 0.82 to 0.92. Pearson product-moment correlations were used to assess the concurrent validity of the WcS-DAT and all of these correlations were significant at a minimum of $p < 0.05$ level, with many significant results at the 0.01 and 0.001 levels. These results indicated good concurrent validity of the WcS-DAT. In Phase III, the WcS-DAT was evaluated for its ability to show changes in discomfort over time and with the introduction of novel, user adjustable wheelchair seating. Both the General Discomfort Assessment score (GDA) and the Discomfort Intensity Score (DIS) were sensitive to changes in seating discomfort level and were adequate for use in detecting differences associated with changes in duration of sitting as well as those associated with use of different seating equipment. Results of this final phase indicated that the WcS-DAT is a useful tool for evaluation of wheelchair seating discomfort in a research or clinical environment.

PREFACE

Though being a doctoral student sometimes seems a solitary venture, this is far from the truth. I would like to gratefully acknowledge those who were instrumental along the way and assisted me in attaining this goal.

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1.0 INTRODUCTION

1.1 THE PROBLEM

Wheelchair-seating discomfort has not been extensively investigated in the field of wheelchair seating research. In fact, there currently exists no validated tool for use in quantifying seating discomfort for persons who use wheelchairs. This lack of a tool has greatly impeded progress in researching this important issue. While it is true that wheelchair seating discomfort is subjective in nature, this does not preclude the ability to quantify and study this important wheelchair seating outcome. Discomfort is a frequent and prevalent problem among wheelchair users. Bardsley (1984) surveyed multiple populations of wheelchair users and found discomfort was one of the wheelchair seating problems commonly identified by individuals with muscular dystrophy, multiple sclerosis, rheumatoid arthritis and spinal cord lesions. In a 1991 study of individuals in skilled nursing facilities, discomfort and impaired mobility were the most frequently reported problems associated with wheelchair use (Shaw & Taylor, 1991). Similarly, two studies of seating needs of elderly nursing home residents found that discomfort was a significant and highly prevalent problem (Shaw, 1993; Shaw, 1992). Furthermore, discomfort has been shown to reach such levels as to cause the wheelchair user to spend more time in bed (Herzberg, 1993). This may lead to decreased quality of life, impaired ability to participate in functional activities and increased incidence of problems associated with being bedfast including decubitus ulcers and pneumonia (Herzberg, 1993). Weiss-Lambrou (1999) studied consumer satisfaction with wheelchair devices and found that the most important consumer criterion for

satisfaction with a wheelchair was comfort, but that it was evaluated by many as the least satisfying feature of their wheelchair (Weiss-Lambrou, Tremblay, LeBlanc, Lacoste, & Dansereau, 1999). Scherer (1996a) has identified discomfort as a contributing factor in what she describes as partial or reluctant equipment use. Partial equipment use is characterized by (1) use of a device for less than the optimal length of time or (2) reluctant use of the device (Scherer, 1996a). Partial use is an important concept because it is closely related to equipment abandonment, but individuals who rely on wheelchairs for primary mobility are unable to completely abandon their wheelchairs without sacrificing all mobility. Due to the prevalence of discomfort among wheelchair users and all of these possible negative outcomes, seating discomfort is an important problem related to use of wheelchairs and warrants further investigation.

1.2 GOALS AND HYPOTHESES

The purpose of the research presented in this dissertation was to develop and test a Wheelchair Seating Discomfort Assessment Tool (WcS-DAT) using a prototype dynamic seating system (PTS2) to elicit the comfort-discomfort continuum in sensate wheelchair users. This research is presented in three phases. Phase I is a descriptive study using ethnographic research techniques to investigate "wheelchair seating discomfort" in the target population and to determine how wheelchair users define this construct and other associated factors. This phase is used to guide the development of the WcS-DAT, which is then evaluated for reliability, validity and efficacy in phases II and III. Phase II is a test-retest reliability study of the WcS-DAT to determine the basic reliability and validity of this assessment tool when used by representatives of the target

population. Phase III involves testing of a user adjustable wheelchair seating system prototype (PTS2) to investigate the efficacy of the WcS-DAT in quantifying discomfort over time and with the introduction of a novel seating environment.

Phase I is not associated with any specific research hypotheses, but does have a research objective. This objective is development of the WcS-DAT – a clinical and research evaluation tool effective for quantifying the level of seating discomfort in a wheelchair-seated individual. Phase II has one associated hypothesis: (1) Participants with severe motor impairment and intact sensation, using the WcS-DAT will be able to reliably quantify the level of discomfort they feel after a minimum of 2-hours using a wheelchair. Phase III also has one associated hypothesis: (2) Persons who use wheelchairs and have intact sensation will demonstrate a difference in discomfort when provided with the capacity to self-adjust their seated posture and their support surface characteristics with a dynamic seating device compared to their regular wheelchair.

1.3 CONSIDERATIONS GUIDING THIS RESEARCH

To develop the WcS-DAT, more information about seating discomfort experienced by wheelchair users was necessary. While the constructs of comfort and discomfort have been extensively evaluated in the office environment by Helander (1997) and Zhang (1996), the only exploration of them among wheelchair users was done in a preliminary study by Monette, et al. (1999). In Monette's study, a focus group research format was used with wheelchair users to differentiate the discomfort factors already identified in other populations (e.g. office workers) from those specific to wheelchair users. Although this provided valuable information regarding some of these differences, more investigation of this topic is warranted. Phase I of this study

utilizes a semi-structured interview-based qualitative research design using ethnographic techniques (Bailey, 1991). The topic of investigation was wheelchair seating discomfort. The informants selected to participate are all experts as they all sit for more than 8 hours per day in wheelchair seating systems and they all have experienced wheelchair seating discomfort.

For Phase II and hypotheses 1 testing, a test-retest single group research design is used for reliability testing. This phase involved the use of 30 subjects. Subjects complete the WcS-DAT four times during the course of one week. This allowed verification of test/re-test reliability. In addition to the use of the newly developed WCS-DAT, similar concurrent measures of discomfort (developed for use in other populations) and a commonly used pain assessment tool were used for cross validation. These measures are tools already validated in the literature for use with other populations.

Phase III of this research followed a single subject ABCA/ACBA multiple baseline, alternating conditions design (Ottenbacher, 1986). Six subjects participated in this phase. Two alternating treatment designs were used – ABCA and ACBA. This phase of research was designed for hypothesis two and three testing. During the course of this research, the WcS-DAT was also evaluated for its performance and sensitivity to detecting changes in wheelchair discomfort over time and with the introduction of a wheelchair seating intervention. In order for the WcS-DAT to be a valuable research or clinical outcomes measurement tool, it must not only be reliable, but also be sensitive to actual changes in wheelchair seating discomfort. This phase of research provided valuable information on the performance of this tool in a longitudinal context in which seating discomfort was expected to change.

1.4 ORGANIZATION OF THIS DISSERTATION

The body of this dissertation includes three research papers (chapters 4, 5 and 6), each presenting one of the phases of research mentioned above. Chapter 2 of this dissertation is an extensive review of the relevant literature, too lengthy for inclusion within the structure of the individual research papers, but containing important background information. Chapter 3 reports the methods and results of two preliminary research studies that were done to investigate the problem of wheelchair seating discomfort in the target population, to initiate the development of the WcS-DAT tool and to guide the development of the user adjustable seating system for the PTS2 test wheelchair used in Phase III testing. This information is critical to decisions made regarding the design and implementation of the current study. In Chapter 4, the methods and results for the phase I research – development of the WcS-DAT – are presented. Chapter 5 reports the methodology and results for the reliability and validity testing of the WcS-DAT (Phase II) and consists of the second manuscript. Chapter 6 contains extensive reporting of the methodology and results from the Phase III testing – the single subject design phase of this research study. The final chapter – Chapter 7 is a summary of the results and overall conclusions from this research and some suggestions for future research in this area. There are also several appendices that include all of the data collection instruments used in the multiple research phases.

2.0 REVIEW OF RELEVANT LITERATURE

2.1 BACKGROUND AND SIGNIFICANCE OF THE PROBLEM

Individuals with multiple sclerosis (MS), amyotrophic lateral sclerosis (ALS), muscular dystrophy (MD), and post polio syndrome (PPS) comprise the largest population of wheelchair users with severe motor impairment and suitably intact sensation. This is an important population due to its relative size – a combined 150,000 wheelchair users in this country. In spite of the magnitude of this group, the majority of wheelchair seating research is focused on the population of wheelchair users with spinal cord injuries resulting in quadriplegia and paraplegia – a population of approximately 90,000 wheelchair users (Kaye, Kang, & LaPlante, 2000).

Research is just beginning regarding the problems associated with long duration wheelchair use among individuals with the above-mentioned disabilities. One of the major problematic outcomes – wheelchair seating discomfort – is explored by this dissertation research. There are two general research topics related to wheelchair seating discomfort. The first involves defining the constructs and problems of "discomfort" and "comfort" – their meaning, previous research, and implications for the wheelchair using population. The second pertains to the effectiveness of a newly developed, user adjustable seating intervention – a relatively new field of intervention and research when applied to individuals who use wheelchairs. The

interplay of these areas is critical to the future development of wheelchair seating technology and outcomes research.

It has been documented that prolonged sitting, particularly in a restricted environment, leads to increased levels of discomfort or pain. Several researchers have investigated this phenomenon, including Helander & Zhang, (1997); Hertzberg, (1972); Lee & Ferraiuolo, (1993); Shackel, Chidsey, & Shipley, (1969); Shen & Vertiz, (1997) and Zhang et al., (1996). Prolonged sitting occurs in office environments where individuals must sit for prolonged periods of time as they work; in the automotive environment where individuals drive long distances without stopping; in the aviation environment where pilots fly for extended hours; and in wheelchair seating environments where individuals who have severe mobility impairments must sit all day. One problem common to all of these populations is discomfort and pain related to restricted mobility over time.

2.2 COMFORT AND DISCOMFORT

One of the primary challenges in researching wheelchair seating discomfort is defining discomfort and determining how it relates to its opposite, and more commonly used term, comfort. In his original studies, Shackel (1969) used comfort and discomfort as opposite ends of a continuous spectrum of sensation. Several other researchers (Branton, 1969; Lee, Schneider, Reed, Saito, & Kakishima, 1991; Zhang et al., 1996) separated the concepts of comfort and discomfort and focused their attention on the evaluation of discomfort. Branton (1969) went as far as redefining the discomfort continuum as a continuum from a point of indifference at one end to a point of severe discomfort at the other and eliminated the concept of comfort altogether.

Although this debate remains unresolved, most researchers have continued to use assessments based on a continuum from comfort to discomfort as a component of their studies (Chesney, Hsu, Wright, & Axelson, 1995; Christiansen, 1997; DiGiovine et al., 2000). For this research, a comfort-discomfort continuum is used in addition to a factor-related approach described by Zhang (1996).

In one large study of office workers (Zhang et al., 1996), comfort and discomfort were determined to be multifactorial in nature and each was related to multiple elements of the seat and the environment. Discomfort was the factor more easily described. Zhang (1996) also found that discomfort was related to joint angles, muscle fatigue, and pressure distribution problems that caused pain, numbness, stiffness, or other negative sensations. Feelings of discomfort were found to increase with time spent in a seat or when limited to movement in one task in an office environment (Zhang et al., 1996). Comfort was more difficult to define and has not been extensively investigated in the literature (Christiansen, 1997; Fubini, 1997; Shackel et al., 1969). In a follow up study these factors were delineated more clearly (Helander & Zhang, 1997). Helander and Zhang (1997) found that comfort was based on feelings of relaxation, general well-being and the aesthetic impression of the chair itself. In a similar study involving persons who use wheelchairs, the feelings of stability and satisfaction were added to this list (Monette et al., 1999). Because of the difficulty in defining and describing comfort, its antonym, discomfort is the component most often evaluated in research studies.

A common theme of research into discomfort is that discomfort is related to the duration of time in a confined or restricted position, such as sitting in a chair in an office, sitting in a car while driving, or sitting in the cockpit of a jet. Typical solutions have included: proper contouring of a seat for maximal pressure distribution (Hertzberg, 1972), optimizing upholstery

characteristics and providing thermal comfort (Fubini, 1997), and the introduction of a dynamic element to allow seated individuals to move and adjust their positions (Elton & Hubbard, 1993; van Dien, de Looze, & Hermans, 2001). Dynamic seating for individuals who use wheelchairs has been studied in the context of pressure relief (Burns & Betz, 1990; Koo, Mak, & Lee, 1995) and the management of extensor spasticity (Ault, Girardi, & Henry, 1997), but few have researched the impact of dynamic seating elements on comfort (Parent, Dansereau, Lacoste, & Aissaoui, 2000). This dissertation research expanded on the knowledge gained in previous research on comfort and discomfort management for individuals who are seated by exploring its applicability to individuals who are seated in wheelchairs.

2.3 RELATED RESEARCH

A large body of research on seating comfort is related to the field of office seating design. Likewise, research in automotive and aeronautic cockpit seating design has provided a general understanding of the concepts of seating comfort and discomfort. These bodies of literature will be reviewed because of their potential to guide research on seating discomfort among sensate wheelchair users.

2.3.1 Office seat design research

Comfort and discomfort research in the field of office seat design has illuminated several problems and potential solutions in seating. These problems consist of discomfort and pain in several regions of the body associated with prolonged sitting (Corlett & Bishop, 1976, Shackel,

et al., 1969) and a limited ability to tolerate the seated position (Zhang et al., 1996). Many solutions have been evaluated, but the most successful focus on dynamic systems incorporating spring loaded components used to allow office workers to move while they sit (Fenety, Putnam, & Walker, 2000). Individuals who work in office settings engage in prolonged sitting (Vergara & Page, 2002) comparable to individuals who rely on wheelchairs for all of their mobility. Although office workers studied were unimpaired, they share problems related to seating discomfort and pain (Corlett & Bishop, 1976; Drury & Coury, 1982; Helander & Zhang, 1997; Shackel et al., 1969; Zhang et al., 1996). Researchers in this field have developed tools, such as the General Comfort Rating Scale (Shackel et al., 1969), the Body Area Discomfort Map (Corlett & Bishop, 1976) and the Chair Evaluation Checklist (Helander & Zhang, 1997), to assess or rate levels of seating comfort and discomfort in this unimpaired population. Other researchers have used these tools in the assessment of office and home furniture to guide development of new products (Fenety, Putnam, & Walker, 2000; Le Carpentier, 1969; Sweeney & Clarke, 1991). While this research has enhanced the understanding of comfort in the unimpaired population, only Monette (1999) has investigated the applicability of this information to the population of wheelchair users. Monette (1999) applied the work of Helander and Zhang (1997) to develop a chair feature evaluation for individuals who use wheelchairs. The outcome of her study became one component of a discomfort assessment tool specific to individuals who use wheelchairs. However, no further research has been conducted on the psychometric properties of this tool and the tool itself was never validated for research purposes.

2.3.2 Automotive/aeronautics industry research

Research in the automotive seat design and aeronautic industries has also enhanced our understanding of seat comfort and comfortable seat design (Kolich, 2003). This body of research is focused around the study of three main variables – time spent in a seated position, the shape of the seat itself, and the pressure distribution of a person's body weight in the seat. The primary contribution of these studies is focused on the temporal aspect of comfort, namely, (a) comfort tends to decrease as time spent in the seat increases, and (b) short duration trials may not adequately determine what elements of a seat will be comfortable over time (Lee et al., 1991; Pywell, 1993; Shen & Vertiz, 1997). Automotive and aeronautic researchers also focused on interventions that would improve comfort and investigated the relationship between certain objective measures, such as pressure distribution or EMG activity, with subjective assessments of comfort (Lee et al., 1991; Pywell, 1993; Shen & Vertiz, 1997). For example, Hertzeberg (1972) and Cohen (1998) found a positive relationship between comfort and increased pressure distribution across a maximal surface area. Moreover, both concluded that contoured seat surfaces were more comfortable than flat surfaces in airplane cockpit seat studies. Similarly, Elton and Hubbard (1993) found that a contoured surface with multiple adjustable features was more comfortable in automobile seating than a non-contoured surface with minimal adjustment. A great deal of the focus in this research has been on the properties of seat cushions related to pressure (Ebe & Griffin, 2000, 2001) because of the convincing evidence that the correct amount of pressure exerted in proper locations will lead to increased seating comfort overall.

Other factors related to seating comfort have also been investigated in the automotive seating arena. Included among these is the effect of thermal comfort on overall seating comfort (Brooks & Parsons, 1999), and the effects of vibration on comfort (which has also been

investigated in the field of wheelchair seating discomfort) (Matsumoto & Griffin, 2002). Thermal and vibration factors have been considered in this wheelchair seating discomfort research as their effects on the discomfort of wheelchair users is largely unknown at this time. The research in the automotive industry may once again, guide the wheelchair seating research in these areas.

2.4 RESEARCH INVOLVING WHEELCHAIR USE AND PAIN

There has been a significant amount of research devoted to the prevalence and causes of pain and wheelchair users with various disabilities. This research includes topics such as low back pain in persons with spinal cord injuries (Chantraine, Bosson, Malaise, Onkelinx, & de Leval, 2001), hip pain experienced by wheelchair users with cerebral palsy (Hodgkinson et al., 2001), neck and upper back pain among individuals who use wheelchairs for all of their mobility (Boninger et al., 2003), upper limb and shoulder pain among individuals with late effects related to poliomyelitis (Koh, Williams, & Povlsen, 2002; Werner, Waring, & Maynard, 1992), and the largest topic area by far – shoulder pain related to wheelchair use, particularly among those with spinal cord injuries (Burnham, May, Nelson, Steadward, & Reid, 1993; Curtis, Drysdale et al., 1999; Sinnott, Milburn, & McNaughton, 2000).

Much of this research is quite focused in nature – on one particular pain syndrome (e.g. shoulder pain) or on one particular population (e.g. individuals with polio). In spite of this high degree of focus, some general conclusions are found across areas including: pain has a negative affect on an individual's activity level (Boninger et al., 2003), causes increased medical visits (Boninger et al., 2003; Chantraine et al., 2001), and may impair an individuals functional

capabilities (Boninger et al., 2003; Chantraine et al., 2001; Willen & Grimby, 1998). The prevalence and implications of shoulder pain have even led to the development of a specialized evaluation tool for quantification of shoulder pain in wheelchair users (Curtis et al., 1995a, 1995b) and the development of a related intervention program (Curtis, Tyner et al., 1999).

While some of these researchers acknowledged the impact of wheelchair seating and postural support on these pain syndromes (Chantraine et al., 2001; Hodgkinson et al., 2001; Sinnott et al., 2000), most focused on the internal body structures or root causes rather than on the influence of the wheelchair seating environment (Curtis, Drysdale et al., 1999; Werner et al., 1992). None of these researchers explored the topic of postural discomfort as it related to wheelchair seating or even as it related to the specific pain syndrome of interest. Although this research has made a significant contribution in the field of pain research and management, it has little to say that directly relates to postural support and positioning that may impact the important area of wheelchair seating discomfort.

2.5 WHEELCHAIR SEATING COMFORT AND DISCOMFORT RESEARCH

Research related to the comfort-discomfort continuum in wheelchair seating is limited. Several studies (Batavia & Hammer, 1990; Troy, Cooper, Robertson, & Grey, 1997; Weiss-Lambrou et al., 1999; Zacharkow, 1988) evaluated consumer satisfaction and identified discomfort as a problem in wheelchair seating. In addition to this, researchers (Boothby, 1984; Chesney et al., 1995; Monette et al., 1999; Nelham, 1984) have also examined the concepts of comfort and discomfort as they relate to individuals who use wheelchairs, finding that the way individuals who use wheelchairs describe comfort and discomfort differs from the way unimpaired

populations describe comfort and discomfort. In a Canadian study unlike any others, Gibson, Albisser, and Koreska (1975) developed a seating system designed to decrease discomfort in a population of wheelchair users with muscular dystrophy. They found that the seating system was effective at providing comfort through enhanced postural support not found in previously used wheelchairs. In a comfort-related study, DiGiovine et al. (2000) investigated the ride comfort of various manual wheelchairs. Similarly, VanSickle, Cooper, Boninger, and DiGivioine (2001) analyzed vibration occurrence in manual wheelchair propulsion and found that they exceeded the ISO standard "fatigue-decreased performance boundary" which could increase fatigue levels and result in discomfort for manual wheelchair users. While these studies have begun to examine the comfort-discomfort continuum with wheelchair-seated individuals, they have neither successfully identified a comprehensive methodology for assessing comfort and discomfort, nor developed definitive seating devices that minimize discomfort and promote comfort.

2.6 SIGNIFICANCE OF THE PROBLEM

In spite of the prevalence and importance of discomfort, most research in the field of wheelchair seating has been focused on problems associated with pressure and pressure-related skin breakdown (Koo et al., 1995) or postural management of individuals with spasticity-related problems, such as those with cerebral palsy. Because of the costs and health problems associated with pressure ulcers, this has remained the focus of much seating research. Another area of research with individuals who use wheelchairs focused on the performance characteristics of the wheelchairs themselves (Cooper et al., 1997). While these areas are highly critical to meeting the health and functioning needs of individuals who use wheelchairs, the issue of discomfort has been largely overlooked and is just now coming to the attention of the research community.

2.7 SIZE OF THE TARGET POPULATION

Because there is no direct measure of the prevalence of discomfort among wheelchair users, an indirect measure will be used based on the size of the target population and the prevalence information that is known from the literature. The target population of wheelchair users for this study is made up of individuals who have problems with discomfort due to their severe motor paralysis and are unable to shift their weight or re-position themselves in their seats. Additionally, they have relatively intact sensation and are able to feel discomfort and pain at the seat-buttock interface or other areas of their body. Such characteristics are common to individuals with diagnoses including: multiple sclerosis (MS), muscular dystrophy (MD), amyotrophic lateral sclerosis (ALS), post-polio syndrome (PPS), Guillian Barre syndrome, and severe debilitation found in frail elders, often due to arthritis or other musculoskeletal conditions.

While it is difficult to determine the size of the sub-population of sensate wheelchair users, there are some helpful statistics related to wheelchair use and the prevalence of diagnostic groups associated with severe motor impairment and intact sensation. Jones and Sanford (1996) quantified nearly 1.4 million manual wheelchair users and 96,467 powered wheelchair users among non-institutionalized individuals in the United States. Another source, the NIDDR Disability Statistics, similarly identified 1.5 million manual wheelchair, 155,000 power wheelchair, and 142,000 scooter users (Kaye et al., 2000). These figures, from 1990 National Health Information Survey data, indicated a doubling of the wheelchair using population from 1980 to 1990.

Multiple Sclerosis is the third leading cause of wheelchair use among all age groups with 82,000 individuals reporting MS as the primary reason they use a wheelchair (Kaye et al., 2000). When looking at ages 18 – 64 (a group likely to be living in the community) MS is actually the number one cause for wheelchair use with 58,000 individuals or approximately 10% of all individuals in this age group who use wheelchairs. The prevalence of wheelchair use for those with ALS is also quite high – 32,000 wheelchair users of all ages and 14,000 wheelchair users age 18-64 (Kaye et al., 2000). The primary cause of wheelchair use in all age groups is cerebrovascular accident and the second is osteoarthritis. These populations are also known to have difficulties with discomfort and pain. Muscular dystrophy is categorized with "other CNS disorders" and this category accounts for an additional 37,000 wheelchair users (Kaye et al., 2000). If combined, these figures add up to 150,000, or 10%, of all non-institutionalized wheelchair users in this country.

3.0 PRELIMINARY RESEARCH

Two pilot studies were conducted to determine the prevalence of discomfort and the potential effectiveness of a dynamic seating intervention at improving comfort. The first study involved the use of a questionnaire-based interview to determine the importance of comfort in a small sample of the target population. The second study introduced a dynamic seating device to a small sample of participants to obtain their feedback based on a limited duration trial of this equipment. Nine participants completed the first study and six participants completed the second study. The results of these pilot studies are summarized below.

3.1 PILOT STUDY I

3.1.1 Participants

For this pilot study, a convenience sample of nine participants was recruited from the target population in the greater Pittsburgh area. The inclusion criteria were: (a) having a diagnosis of MS, MD, ALS, or post polio syndrome, (b) being 18 years old or older, (c) having used a wheelchair or scooter for at least three months, (d) using a wheelchair or scooter as the means of primary locomotion (all day), and (e) having some problems related to discomfort. Individuals were excluded if they had experienced a pressure ulcer within the last year.

3.1.2 Method

Pilot study I was a descriptive study using a structured interview. All experimental procedures were approved by the University of Pittsburgh's Institutional Review Board prior to recruitment of any participants. The participants were visited in their homes or other locations of their choosing in order that they might feel most comfortable. After a detailed explanation of the study and signing of an informed consent form, a structured questionnaire format was used to interview the participants. Both closed-ended and open-ended questions were included. The questionnaire contained demographic information questions, a description of the participant's current wheelchair, and individual suggestions for designing an "ideal" wheelchair seating system. A sample of these questions appears in Table 3-1. (The complete questionnaire is enclosed in Appendix A). Descriptive statistics and weighted rank order calculations were used to analyze the responses.

Table 3-1: Pilot study one sample questions

Question number	Question text	Format of answer
Part two, number 1	On an average day, how long do you spend in your seating system?	Closed-ended – number of hours
Part two, number 2	What is a typical reason for getting out of your seating system?	Closed- or open-ended – given 5 choices or able to list their own reason
Part three, number 4	Do you ignore your discomfort to function at your current level?	Closed-ended – yes or no
Part three, number 8	How do you currently manage discomfort in your seating system?	Closed- or open-ended – given 5 choices or able to list their own method
Part four, number 4	How important are these features of a seating system to you? Rated on a scale of 1 – 10, seven items: comfort, safety, mobility, ability to perform self care tasks, independent use of all features, ability to adjust multiple features, ability of caregiver to adjust features	Rated on a scale from 1 to 10: 1 – least important, 10 – most important

3.1.3 Results

Nine participants completed the questionnaire-based interview for this phase. All nine had intact sensation determined through testing of light touch and proprioceptive sensory awareness on their lower extremities. Six of these were interviewed in their home and 3 were interviewed in a laboratory setting. The age of participants ranged from 18 to 66 years old with a mean age of 41 years old. Seven of the participants were male and 2 were female. Primary diagnoses included: ALS – 2 participants, MS – 2 participants, MD – 5 participants. Additional descriptive data are summarized in Table 3-2. Five participants interviewed used tilt in space seating systems (4 powered and one manual); 3 participants used reclining seating systems (2 powered and one manual). Seven participants used powered mobility systems and 2 participants used manual systems.

Table 3-2: Pilot study one sample characteristics

Parameter	Mean (n=9)	Range
Age (in years)	41	18 to 66
Time in chair (in hours)	15	8 to 24
Height (in inches)	67	50 to 74
Weight (in pounds)	159	94 to 220

The range of hours the participants spent in their chairs on an average day was 8 to 24 with an average of 15 hours per day. Participants reported three main reasons for getting out of their wheelchairs – (1) fatigue (3 participants), (2) functional need (5 participants) and (3)

discomfort (1 participant). When asked if they experienced discomfort in their wheelchairs, all 9 reported that they did experience some level of discomfort. Five reported experiencing this discomfort on a daily basis, 3 reported experiencing discomfort at least once per week and one reported experiencing discomfort after only a few hours in the chair. All 9 reported that they routinely ignored discomfort to participate in functional activities. The most common site of discomfort was the low back (7 participants reporting this as an area of discomfort) and the second most common site was the buttocks (6 participants). Most participants reported limited options for relief of discomfort. Three reported getting out of their chairs to relieve discomfort, 4 reported use of pain medications, 6 reported asking someone to reposition them in their chair, 4 reported repositioning themselves in their chair to the best of their abilities and one reported using the power tilt option to relieve discomfort. When asked about a history of skin breakdown problems, 5 participants reported that they had experienced at least one episode of skin breakdown since they began using wheelchairs full time. Pertinent results are summarized in Table 3-3.

Table 3-3: Summary of Interview Results

Question posed:	Response	n	Response	n	Response	n
What is the reason for getting out of the chair?	Functional need	5	Fatigue	3	Discomfort	1
How often do you experience discomfort?	Every day	5	At least once per week	3	After a few hours	1
What methods do you use to relieve discomfort?	Get help to reposition	6	Pain medications or reposition self	4	Get out of the chair	3
Most common sites of discomfort	Low back	7	Buttocks	6	Legs	5
Do you experience discomfort?	Yes	9	No	0		
Do you ignore discomfort to function?	Yes	9	No	0		
Do you have a history of skin breakdown	Yes	5	No	4		

Weighted rank order (WRO) was computed for two parameters. The WRO for each parameter was calculated by multiplying the number of responses by the value of the response (from 1 –10) and then adding all resultant values and finally assigning a rank. The weighted rank order of various wheelchair attributes is as follows: comfort and mobility were tied as the most important attribute of a wheelchair, the ability to adjust multiple features was second, independent use of all features of the chair was third, the ability to perform self care tasks in the chair was fourth, and safety was fifth. For details on these ranks, see Table 3-4. The next ranking was performed on the necessity or importance of adjustability of various features of the chair. An adjustable control mechanism was ranked most important, adjustable leg rests was ranked second, adjustable seat temperature (if possible) was ranked third, adjustable arm rests was ranked fourth, adjustable head support was ranked fifth, adjustable lateral supports was ranked sixth, and an adjustable seat belt was ranked seventh and last of the features listed.

Table 3-4: Weighted rank order of seating system attributes

Parameter being ranked:	Weighted rank score	Rank order location
Seating system attributes:		
Comfort	83	Tied - 1
Mobility	83	Tied - 1
Ability to adjust multiple features	81	3
Independent use of all features	71	4
Ability to performs self care in chair	67	5
Safety	66	6
Ability for care-giver to adjust multiple features	60	7
Importance of adjustability:		
Control mechanism location*	66	1
Leg rests	62	2
Seat temperature	52	3
Arm rests	50	4
Head support*	43	5
Lateral supports*	17	6
Seat belt*	16	7

3.1.4 Discussion

The findings of this pilot study were in agreement with past research in this area and supported the need for the research put forth the remainder of this dissertation. All of the participants in this study indicated comfort was very important to them. The participants also agreed unanimously that discomfort is a significant problem for them, even if they felt that they were able to ignore discomfort to function (which most stated). The analysis of the functional impact of discomfort is more difficult. When asked directly if discomfort limited their time in their chairs or limited function, all replied in the negative. However, when asked what they did to relieve discomfort, 3 reported that they got out of the chairs they described "necessary for function" to manage discomfort. These findings reiterated the importance of research on a dynamic seating intervention proposed as a potential method of mitigating discomfort.

3.2 PILOT STUDY 2

The second pilot study focused on the development and initial testing of a dynamic seating system. The goal of this study was to obtain some specific feedback from individuals in the target population to guide further development of the dynamic seating system for use in future research.

3.2.1 Participants

For this pilot study, a subgroup of 6 participants from Pilot Study I were enrolled. The inclusion criteria were: (a) having a diagnosis of MS, MD, ALS, or post polio syndrome, (b) being 18 years old or older, (c) having used a wheelchair or scooter for at least three months, (d) using a

wheelchair or scooter as the means of primary locomotion (all day), (e) having some problems related to discomfort and (f) having intact sensation on their buttocks and lower extremities. Individuals were excluded if they had experienced a pressure ulcer within the last year. This group included 4 participants with Muscular Dystrophy, one with ALS, and one with MS. One female and 5 male subjects participated. One of these participants used a manual wheelchair, the remainder used power wheelchairs as their primary means of mobility.

3.2.2 Equipment

The pilot test seat (PTS1) used for this pilot study consists of an Amobi truck seat mounted on a Permobil Chairman power wheelchair base (see Figure 3-1). The PTS1 had six inflatable air bladders – four in the seat area and two in the back – that were controlled through a custom, push button interface (see Figure 3-2). This interface was constructed to allow access of the controls to a variety of motor-impaired individuals. This interface also contained the controls for the tilt and recline systems of the chair. The power leg motion and power seat lift were not controlled by the individual in the chair, but the researcher was able to adjust them upon request. The pneumatic controls were operated by a series of solenoids and a pneumatic system designed and custom built for use with this seat. This was necessary to allow the PTS1 to integrate with a wheelchair base.

Figure 3-1: PTS1 - test seat

The control interface provided the user direct control over all of the pneumatic bladders in the seat and the back (with the exception of the lateral supports) and also the position of the system in space through the use of power tilt and power recline. This allowed participants to compare these dynamic features and provide feedback on their relative effectiveness during this short-duration sitting test.

Figure 3-2: Control interface for PTS1

3.2.3 Method

For Pilot Study II, a descriptive study was implemented using a participant-observer design, followed by an interview. All of the participants came to the School of Health and Rehabilitation Sciences at the University of Pittsburgh to test the PTS1 dynamic seating system. The participants signed videotape recording releases and were instructed in proper operation of all features of the chair. Participants were transferred into the PTS1 and the control interface operation was demonstrated to them. All participants sat in the PTS1 for a minimum of 1 hour and a maximum of 1 hour 15 minutes. During this time, they were free to make the desired adjustments to the position in space or the inflation levels of all components at any time. They all watched a generic videotape that was interrupted approximately every 15 minutes to allow them to respond to a series of questions related to the PTS1 and their comfort levels.

There were 11 structured questions used for this interview process, some only asked at the beginning of the interview, and some asked repeatedly throughout the interview. The entire session was videotaped to record verbal responses as well as any associated body language or facial expressions.

The questions asked at the beginning of the interview process were:

1) Please describe your current level of comfort in this seat:
2) Please describe the sensations you are feeling sitting in this seat:
3) Would you like to make any adjustments to the seat surface or the position of the seat tilt or recline?
4) Would you like your legs re-positioned?
5) Please describe any adjustments you would like to make that are not available on this seat:
6) Please describe the features of this seat that allow you to be most comfortable:
7) Please describe any features that are not on this seat that you feel would allow you to sit more comfortably:
8) Do you have any other comments you would like to share regarding this seat or a future seat to be designed?

The questions asked repeatedly throughout the interview process were:

1) How important would it be to have lateral supports that could inflate to give more upper body support?
2) If these lateral supports are important, should they inflate both sides at the same time or separately?
3) When the back of the chair reclined there is some friction happening between you and the chair back; is this uncomfortable to you?

The questions above were posed to the individual after transfer into the PTS1 chair and at approximately 15-minute intervals throughout the evaluation process. In addition to the questions above, follow up probing questions based on initial responses were asked that differed from individual to individual. Participants were also free to comment on issues not addressed by these particular questions and to make suggestions or comments at any time during the evaluation process. Most participants were questioned 4 – 5 times during the session.

3.2.4 Data analysis

After completion of the session, the verbal responses to the questions and all other dialogue were transcribed into a written account and all transcriptions were then combined into a summary document. A cross-interview analysis of each question was performed to determine the presence of consistent themes among the subjects' responses and comments.

3.2.5 Results

Five of the participants were physically able to operate the interface independently, one individual was not because of his impairments and the position of the control interface on the wheelchair. This individual directed the researcher in all adjustments to the seating system desired. Several response themes developed from this brief in-chair testing. These responses will be used to guide development of the next test seat (PTS2).

The overall response to the PTS1 was quite positive. In terms of overall comfort, the majority of the participants felt that the PTS1 seating was very comfortable and 4 of the 6 felt it was more comfortable than any wheelchair seat they had ever used. Two participants found it was as comfortable as their own wheelchair seat currently in use. The initial comfort response

and follow up comfort responses remained similar for all subjects. Several subjects actually reported improving levels of comfort after being in the PTS1 for a longer duration because of their ability to "fine-tune" the adjustments and make the seat more comfortable as time progressed. Related to comfort, all 6 of the participants reported a sensation of increased back support, which made the PTS1 more comfortable than their own chairs. Several subjects described the importance of adjustability. All of the participants preferred having the ability to adjust the amount of lumbar support and 2 participants found the ability to periodically change this and other areas of support allowed them postural shifts that they would be otherwise unable to perform.

Another important feature was independent ability to adjust the seat features. The 5 participants who were able to independently alter the support characteristics found this to be essential and all 6 reported that the chair user should be able to adjust all features of the chair without assistance. Results related to the importance of various features were mixed. Two participants reported the tilt and recline features were the most comfortable features of the chair (neither of these participants had this feature on their current chair), the other 4 reported the pneumatic seat and back components were more comfortable (all 4 of these participants had some type of tilt or recline system on their current chair). In terms of the dynamic nature of the PTS1 seating, three of the participants reported their feelings that the dynamic elements of the seat would be critical at attaining and maintaining a comfortable level of seating over a long duration. One of these participants indicated that having these dynamic features would allow him to perform postural shifts that would prevent him from getting stiff and sore over time.

The participants who tested the PTS1 found all of the dynamic elements helpful in attaining optimal comfort, but reported several features they considered important for additional comfort. These features included: adjustable head and neck supports, adjustable arm and trunk lateral supports, and adjustable lower extremity supports. These additional features are included in the PTS2 to the extent possible based on this input. Overall, participant response was very positive and supported the assumptions concerning essential design criteria for optimizing comfort in the wheelchair.

3.2.6 Discussion

The results of this pilot study indicated that the introduction of dynamic seating, at least in a short duration test, enhanced the comfort of the participants sitting in the chair. This information was used to guide development of the PTS2 seating system, which included all user-controlled adjustments suggested to the extent feasible with available technology.

The results from these pilot studies confirmed that discomfort is a problem in this target population of sensate wheelchair users. Similar to populations of office workers, automobile drivers, and aircraft pilots, this population has discomfort related to the duration of time spent sitting in one position. However, the study population is less able to relieve discomfort through voluntary body movement. As described in the Chapter 2 of this dissertation, several solutions have been tried including the provision of seats shaped to provide maximal pressure distribution, seats and backs at various angles and with various configurations, and seats that have movement or dynamic capabilities. The process of describing and quantifying discomfort has been the subject of research in these related fields. The success of quantifying comfort and discomfort in the office and automotive seating industries lead to a firm belief that this should be possible among wheelchair users as well. The use of dynamic interventions – or seats that can be adjusted under user control has also been documented and provides hope that dynamic seating will also be effective in mitigating discomfort among wheelchair users.

4.0 DEVELOPMENT OF THE WHEELCHAIR SEATING DISCOMFORT ASSESSMENT TOOL (WCS-DAT)

4.1 BACKGROUND

Several researchers have identified the problem of wheelchair seating discomfort (Chesney et al., 1995; Harms, 1990; Herzberg, 1993; Monette et al., 1999; Scherer, 1996b; Shaw, 1992; Weiss-Lambrou, Tremblay, Lacoste, LeBlanc, & Dansereau, 1998). In spite of this, the challenges associated with researching discomfort in a population of wheelchair users have been addressed by relatively few (Chesney et al., 1995; Harms, 1990; Herzberg, 1993; Monette et al., 1999; Scherer, 1996b; Shaw, 1992; Weiss-Lambrou et al., 1998). Even among these researchers, their primary focus was not discomfort, but rather consumer satisfaction (Scherer, 1996b; Weiss-Lambrou et al., 1998) or issues related to function or pressure relief (Chesney et al., 1995).

Wheelchair seating discomfort research is complicated by many difficulties, not the least of which is the subjective nature of discomfort (Christiansen, 1997). Another difficulty is determining what to measure – discomfort or comfort (Shackel et al., 1969). Moreover, researchers often disagree on the meaning and nature of comfort (Christiansen, 1997; Shen & Vertiz, 1997).

Among the significant challenges in studying discomfort is the lack of validated tools quantifying discomfort in the research literature. The tools that have been published have been largely developed based on input from unimpaired individuals (Christiansen, 1997; Corlett & Bishop, 1976; Helander & Zhang, 1997; Shackel et al., 1969; Zhang et al., 1996). Two of the

more widely-used tools are the General Comfort Rating Scale (Shackel et al., 1969) and the Chair Evaluation Checklist (Helander & Zhang, 1997). Others include Barkla's chair assessment tool for rating chairs for a specific purpose (1964), Corlett and Bishop's Body Part Discomfort Scale (1976), and the Chair Feature Checklist used by Drury and Coury (1982) and Fenety et al (2000). All of the aforementioned tools relate to the evaluation of office chairs or other seats used by unimpaired populations. In the wheelchair seating research area there was one attempt to create a comprehensive assessment of wheelchair seat comfort and discomfort (Monette et al., 1999), but to date, there has been no psychometric testing performed on this assessment tool. The lack of a published valid tool specifically designed to quantify wheelchair-seating discomfort prompted this research effort.

4.1.1 Research Question

For this qualitative research task, the primary question was "can individuals with sensation, who use wheelchairs full time (more than 8 hours per day), describe concepts of discomfort and comfort in such a way that a comprehensive tool to quantify discomfort can be developed?"

4.2 METHODS

4.2.1 Participants

After approval by the University of Pittsburgh Institutional Review Board, 10 participants were recruited. Based on experience with qualitative research and the specificity of the topic involved in this research, the investigators estimated it would take approximately 10 interviews to reach a point of data saturation, a requirement for this type of research. Advertisements were placed in

newsletters for the local multiple sclerosis, muscular dystrophy, and amyotrophic lateral sclerosis associations. Participants 1-4 volunteered based on seeing these advertisements. Therapists knowledgeable regarding the project nominated the remaining six participants. Participant characteristics are described in Table 4-1.

Table 4-1: Participant characteristics

Participant	Age	Gender	*Diagnosis	Vocation or avocation
1	22	male	MD	junior in college
2	45	male	ALS	retired firefighter (disability retirement)
3	66	male	MS	retired engineer
4	57	male	MD	volunteer community based activities
5	33	female	MS	active in her home only – former university student
6	20	male	MD	full time student in vocational training program
7	55	male	MS	retired university professor
8	60	female	MS	retired - disability
9	53	female	polio	therapy technician in rehab hospital
10	90	female	polio	retired – active in her community

* MD = muscular dystrophy, ALS = amyotrophic lateral sclerosis, MS = multiple sclerosis, polio = poliomyelitis or post polio syndrome

Participants were all full-time wheelchair users who had limited ability to shift their weight or change their seated posture -- but had intact sensation. With the exception of Participant 5, all participants used electric-powered wheelchairs for their mobility. See Table 4-2 for additional information regarding the wheelchair use characteristics of the participants.

Table 4-2: Wheelchair use characteristics of Phase I participants

Participant	Length of wheelchair use	Special wheelchair features	Sitting time (hours/day)	Areas of discomfort
1	10 years	power standing	12	back, legs
2	7 years	power tilt, recline and elevating legrests	8	buttocks, neck back
3	>30 years	power recline and power seat tilt	12 – 15	buttocks, back, neck, legs
4	>10 years	specialty seat cushion, no powered seating	12	buttocks, lower body
5	5 – 10 years	contoured seat cushion	8 – 14	back, arms
6	>10 years	special seat cushion	15	buttocks, legs
7	15 years	power tilt system	14	neck, buttocks
8	>5 years	power tilt and recline, power elevating legrests	12	back, buttocks, feet, legs
9	30 years	special seat cushion	>15	back, buttocks, legs
10	>50 years	manual elevating legrests	12	multiple areas

4.2.2 Data Collection

Prior to undertaking any participant interviews the investigator practiced probing interviewing techniques with an experienced qualitative researcher until consistency was achieved. Upon initial contact, the participants were asked to select the interview site where they would feel most at ease during the interview process. Seven participants were interviewed in their homes, two were interviewed at a vocational training center and one (participant 10) was interviewed in the hospital, prior to discharge. After obtaining informed consent a study investigator proceeded with each participant using a semi-structured ethnographic process. Each interview consisted of 10 grand tour questions (listed below), followed by multiple probes emanating from each participant's responses to each of the grand tour questions. Interview questions were open-ended to allow participants to develop and express fully their thoughts and ideas. Grand tour questions were printed in large print on brightly colored cards and as the interviewer moved from one grand tour question to the next, a printed card was placed in front of participants to help them maintain focus on the particular topic of interest. The interviews ranged in length from 20 to 60 minutes with an average of 30 minutes per interview. The grand tour questions used are as follows:

1. When you are sitting in your wheelchair, what does the word discomfort mean to you?
2. When you are sitting in your wheelchair, what does the word comfort mean to you?
3. How are comfort and discomfort alike?
4. How are comfort and discomfort different?
5. What kinds of things cause you to be uncomfortable?
6. What kinds of things allow you to be more comfortable?

7. How are discomfort and pain alike or different?
8. How does using your wheelchair affect your levels of discomfort?
9. How does using your wheelchair affect your levels of comfort?
10. Is there any thing else you can tell me about your experiences with comfort and discomfort that we have not covered?

4.2.3 Data Analysis

The interview tapes were transcribed into text files and prepared for importation into Nu-Dist version 4 (N4) qualitative analysis software (Qualitative Solutions & Research, Pty. Ltd. 1991-1997). The questions and responses were divided into short text units, with each text unit containing no more than one thought or idea. These transcripts were then imported into N4 for the purpose of analysis. See Figure 4-1 for graphical representation of analysis procedures used. Coding of the transcript materials was done immediately following each interview to reduce the potential for data loss and to determine when data saturation was being reached. Coding consisted of analyzing each text unit and assigning it to appropriate general topic area(s) or classification(s) based on its content (Bailey, 1991; Patton, 1990). In this way, all text units are categorized and linked with other text units that have similar meanings or topics. Data saturation was predetermined to be the point when new interview transcripts were fully coded with existing codes and new codes no longer needed to be created. As anticipated, this point was reached at interviews 9 and 10, which were coded simultaneously due to the timing of the interviews.

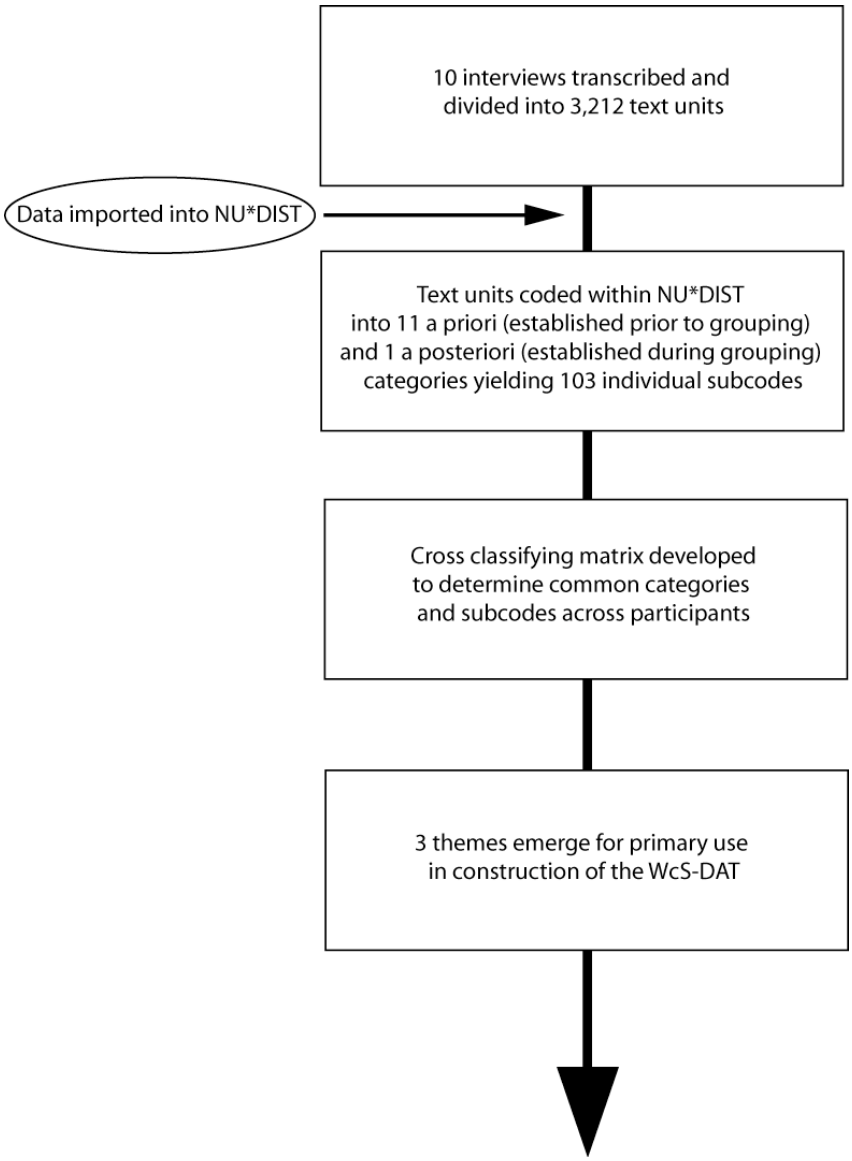


Figure 4-1: Phase I data analysis procedures

A preliminary coding structure was built into the N4 project database that included 11 basic categories. One category contained basic demographic information and the other 10 categories each contained one of the topics covered in the grand tour questions. This gave the coding a preliminary structure and is considered a form of "top-down" coding. The remainder of the coding structure was built using a "bottom-up" coding methodology (Bailey, 1991; Patton, 1990), meaning codes were developed from the actual text of the interview data. After all documents were coded the coding tree was built within the N4 software. Cross-classifying matrices were constructed around each major topic area to assess commonalities across participants. Ideas or descriptors used by greater numbers of participants were considered more essential to the discomfort assessment process. In addition to the cross-classifying matrices, data were triangulated with two different research sources. One data source was a study that examined discomfort among office workers (Zhang et al., 1996) and the other was a similar study done with a population of wheelchair users (Monette et al., 1999). Data from this study matched closely with results from both of these previous studies.

From these data and methods, the content of the Wheelchair Seating Discomfort Assessment Tool (WcS-DAT) was determined and the tool was constructed. The tool was distributed to all research participants for a member-checking process. The investigator conducted a follow-up interview with each participant to confirm the accurate interpretation of their input and the relevance of the tool that was created.

4.3 RESULTS

Overall, 103 unique codes were established to represent the information provided by the participants. These were divided into 12 major categories or themes. Ten of these categories were directly related to the 10 grand tour questions. One was a compilation of themes or ideas that spanned more than one grand tour question. The final category was an expansion of the grand tour question related to wheelchair use. Major categories that emerged from the nodes included: (1) the meaning of comfort, (2) the meaning of discomfort, (3) body areas most affected by discomfort, (4) the impact of using a wheelchair on comfort and discomfort, (5) the similarities or differences of comfort and discomfort, (6) the similarities of discomfort and pain experiences, and (7) the causes or contributors of comfort and discomfort.

The three categories considered to be most essential in quantifying discomfort included: (1) the meaning of comfort, (2) the meaning of discomfort, and (3) the body areas most affected by discomfort. Therefore, information and descriptors in these three categories were primarily used in construction of the WcS-DAT. The participants used 16 unique descriptors of discomfort (see Table 4-3 for examples) and 13 unique descriptors of comfort (see Table 4-4 for examples). Ten body areas were described as being particularly problematic when discomfort occurred.

Table 4-3: Examples of discomfort descriptors used by participants

Discomfort descriptor used:	Number of participants	Number of text units
having aches and pains	10	32
feeling like I need to move	8	30
having pressure points	4	9
feeling poorly positioned	3	19
feeling like I am unable to concentrate	3	7
embarrassment	2	18
discomfort is frustration induced	2	13
discomfort is induced by physical stress	2	4
feeling stiffness	1	11
feeling like I am unstable	1	10
irritability	1	6
just feeling not comfortable	1	6
psychological discomfort	1	1

Table 4-4: Examples of comfort descriptors used by participants

Comfort descriptor used	Number of participants	Number of text units
comfort means the absence of discomfort	5	28
feeling like I am in a good position	4	20
comfort is made up of multiple factors	4	10
comfort means having no pain	4	8
feeling like I am able to concentrate	3	13
feeling good	2	2
not thinking about discomfort	1	6
I can stay in the chair longer	1	4
I feel like I am able to relax	1	3
feeling of relief	1	3
having a good or supportive social environment	1	3
feeling like I can enjoy sitting in chair	1	2
feeling a positive attitude	1	2

The comfort and discomfort descriptors were analyzed to identify commonalities. In this analysis, 8 of the discomfort descriptors and 6 of the comfort descriptors were discussed by at least two of the participants. In the analysis of the body areas involved in discomfort, back and lower-body discomfort were noted by several of the participants, with buttocks being the most frequently identified region for discomfort.

When similar concepts were combined into more global categories, the two strongest themes that emerged were the importance of being able to shift or repositioning one's body to reduce levels of discomfort and the physical symptoms of discomfort. In addition, the critical role of support and positioning provided by a wheelchair was discussed by 9 of the 10 participants. During the follow up interviews with participants (the member-checking process) some of the statements used in the tool required minor wording changes for clarification. After clarification, all participants felt the WcS-DAT content to be appropriate and relevant. No major content changes were recommended by the participants.

The WcS-DAT was developed directly from the information generated in the participant interviews, which was then compared with related research tools and research findings. The result is a three-part tool. Part I of the tool is used to collect information about factors that directly affect discomfort such as the amount of time spent in one position in the wheelchair and whether the individual in the chair was transferred and positioned properly initially. Part II contains 8 statements related to discomfort and 5 statements related to comfort that are rated on a 7-point Likert scale. These statements are all prefaced with "While seated in my wheelchair …" and are as follows:

Discomfort statements used:

1. I feel poorly positioned
2. I feel like I have been in one position for too long
3. I feel like I need to move or shift my position
4. I feel aches, stiffness, or soreness
5. I feel pressure in some part or parts of my body
6. I feel too hot or cold or damp
7. I seek distraction to relieve discomfort
8. I feel uncomfortable

Comfort statements used:

1. I feel no pain
2. I feel stable (not sliding or falling)
3. I feel comfortable
4. I feel good
5. I feel able to concentrate on my work or activities

Part III includes 7 body areas (back, neck, buttocks, legs, arms, feet, and hands) that are rated for the degree of discomfort intensity on a 0 to 10 scale. Space is also provided for the addition of body areas that are not listed. The WCS-DAT concludes with a general discomfort intensity rating on the same 0 to 10 scale.

4.4 DISCUSSION

The prevalence of wheelchair related discomfort has been well established in several studies (Bardsley, 1984; Crane & Hobson, 2002; DiGiovine et al., 2000; Harms, 1990; Monette et al., 1999; Redford, 1993; Shaw, 1992; Shaw & Taylor, 1991; Weiss-Lambrou et al., 1999). Discomfort negatively impacts consumer satisfaction for wheelchair users (Weiss-Lambrou et al., 1999) and overall usability of wheelchairs and seating systems.

The newly developed WcS-DAT is a valid tool for quantifying wheelchair seat discomfort in sensate long-term wheelchair users. The three parts of this tool combine critical aspects of the experience of discomfort as expressed by sensate wheelchair users who sit for 8 hours or more per day. Although several formats for such a tool were suggested in the literature – particularly in the field of ergonomics, this type of tool has not been described in the wheelchair-seating research literature. Quantifying discomfort is essential to the measurement of wheelchair seating outcomes (Weiss-Lambrou et al., 1999).

It is anticipated that the WcS-DAT will have multiple applications. This tool may be useful in clinical settings to evaluate the discomfort-related outcomes of seating interventions. In addition, the WcS-DAT is useful in quantifying discomfort in wheelchair seating research. Data from the WcS-DAT may also be used to guide the design and development of new products to mitigate seat discomfort related to long-duration sitting in a wheelchair.

The validity of the WcS-DAT has been established in this preliminary study, but the sensitivity of this tool to change over time or in detecting discomfort differences among various seating interventions remains unknown. Also, this tool has been developed with a specific population of wheelchair users – namely those with intact sensation and severe difficulty moving. The applicability of this tool to other wheelchair users is unknown at this time.

Future research is needed to determine the sensitivity of this tool in measuring changes in discomfort levels – either due to time factors or due to seating changes. Research is also needed to determine the applicability of this tool to wheelchair users with diagnoses not included in this study or who have different motor and sensory abilities than those described in this study.

5.0 RELIABILITY AND CONCURRENT VALIDITY OF THE WCS-DAT

5.1 BACKGROUND

People who use wheelchairs, particularly those who sit for more than 8 hours per day, often experience discomfort (Scherer, 1996b; Shaw & Taylor, 1991; Weiss-Lambrou et al., 1999). Discomfort leads to negative consumer satisfaction (Weiss-Lambrou et al., 1999), decreased quality of life (Herzberg, 1993), problems related to propulsion ergonomics (DiGiovine et al., 2000), adoption of poor postures to relieve discomfort (Engstrom, 2002) and may impair everyday function and the ability to remain in the wheelchair (Kotajarvi, Basford, & An, 2002). Yet, few researchers have investigated the nature and causes of wheelchair seat discomfort, or possible solutions to this problem (Monette et al., 1999; Shaw, 1992). One of the basic problems with investigating discomfort is that there is no proven way to reliably quantify wheelchair seating discomfort. While there are many validated assessment tools in existence to measure the similar construct of pain (Keele, 1983; Melzack, 1975; Rudy, Turk, & Brody, 1992; Rybstein-Blinchik, 1983; Sworkin & Whitney, 1992; Turk & Melzack, 1992, Jensen, 1992), the development of a tool to quantify discomfort has not had the same attention.

Discomfort in office chairs and vehicle seats has been studied extensively. Several tools have been developed in these fields related to seat discomfort (Corlett & Bishop, 1976; Helander & Zhang, 1997; Pywell, 1993; Shackel et al., 1969; Zhang et al., 1996). These tools have been used extensively to investigate the discomfort associated with long duration sitting by unimpaired office workers (Fenety et al., 2000; Helander & Zhang, 1997) or for assessing specific ergonomic seat designs and comparing products (Barkla, 1964; Le Carpentier, 1969).

Few investigators have attempted to measure seating discomfort among wheelchair users (Monette et al., 1999; Shaw, 1992; Weiss-Lambrou et al., 1999). These researchers have either used an assessment tool developed for a different population, usually an unimpaired population, or have developed their own tools but not conducted extensive psychometric testing of these tools relating to reliability or validity (DiGiovine et al., 2000; Monette et al., 1999; Shaw, 1993; Shaw, 1992).

The Wheelchair Seating Discomfort Assessment Tool (WcS-DAT) was developed using long-term wheelchair users feedback about seating related discomfort (Crane, Holm, & Hobson, 2003). The WcS-DAT consists of three sections or parts. Part I collects general information about factors that directly affect discomfort in one's wheelchair such as the amount of time spent in one position in the chair and whether the individual in the chair was transferred and positioned properly initially. Part II contains eight statements related to discomfort and five statements related to comfort that are rated on a 7-point Likert scale. Part III includes seven body areas (back, neck, buttocks, legs, arms, feet, and hands) that are rated for a degree of discomfort intensity on a 0 to 10 scale. Space is also included for the user to list additional body areas, and for a general discomfort intensity rating on the same 0 to 10 scale. These three parts produce two measures of discomfort – the 13 items in part II make up the General Discomfort Assessment score (GDA) and the items in part III make up the Discomfort Intensity Score (DIS).

5.1.1 Hypotheses

The purpose of this study was to determine the test-retest reliability, internal consistency, and concurrent validity of the WcS-DAT (Crane et al., 2003). Our hypothesis was that the WcS-DAT will allow persons who use wheelchairs and have intact sensation in their buttocks and lower extremities to quantify reliably their levels of discomfort after a minimum of 2-hours sitting in and using their wheelchairs.

5.2 METHODS

5.2.1 Participants

Thirty full time wheelchair users were recruited from the greater Pittsburgh and Johnstown, Pennsylvania regions for participation in the study. All participants used their wheelchairs for a minimum of 8 hours per day, had difficulty shifting their own posture due to motor weakness, and had intact sensation in their buttocks and lower extremities. Sensation was verified by testing with Semmes Weinstein monofilament #6.65 (279.4 grams of force). Diagnostic groups included in this study were multiple sclerosis (n=12), amyotrophic lateral sclerosis (n=4), post-polio syndrome (n=4), and muscular dystrophy (n=10). Although exact distribution of each diagnosis in the population of wheelchair users is unknown, an attempt was made to recruit individuals in each group according to their relative proportions in the population as a whole (e.g. multiple sclerosis has the highest prevalence in the population and it was the largest group recruited for this study).

5.2.2 Method

The research protocol was approved by the University of Pittsburgh Institutional Review Board prior to any research being conducted. Each participant was visited in his or her home for the purposes of obtaining informed consent, completing a screening sensory test procedure, and explaining the research procedures. At the time of the visit, each participant was given a packet of information including written directions, four questionnaire sets, four inner envelopes, and one larger return mailing envelope. Each participant completed one questionnaire set with the researcher on site (if they met the requirement of a minimum of 2 hours sitting in their wheelchair at the time of the visit) or at a later time as needed. Each participant then completed

the three remaining duplicate questionnaire sets over a period of one week. The questionnaire sets were completed in pairs – each pair was completed approximately one hour apart on the same day and the two pairs were completed one week apart. The one hour interval was felt to be short enough that participants' discomfort levels would not have changed substantially, but long enough to minimize any carryover effect from one set to the next. This type of interval has been used in reliability validation of pain measurement scales (Ferraz et al., 1990). Participants were followed up with reminder calls the day prior to scheduled completion of the second pair of questionnaires and were given the option of having a researcher assist them with completion of these questionnaires via telephone.

5.2.3 Questionnaire Content

Each questionnaire set contained the following: the three page WcS-DAT; a one page "average day" rating form; the two page Chair Evaluation Checklist (CEC) (Helander & Zhang, 1997); and the one page Short Form of the McGill Pain Questionnaire (SF-MPQ) (Melzack, 1987). Within each questionnaire set, there were 89 individual items to be completed and the average time to complete all items was 20 minutes. All questionnaires were presented in the same order for each assessment.

5.2.4 Analysis

The data were coded and entered into a data file for SPSS version 11 (SPSS for Windows, release 11.0.1, © SPSS Inc., 1989-2001). Test-retest reliability was performed using the ICC (2,*k*) form. The Intra Class Correlation Coefficient was selected to assess the consistency and average agreement between the two data sets (tests and retests). This scale reflects both the degree of correspondence and the agreement among the ratings and is therefore preferable to

using two separate measures of correlation, such as a Pearson Product correlation and a t-test. (Portney & Watkins, 2000). ICC values range from 0.00 to 1.00 and values over 0.75 indicate good reliability. Values above 0.90 are often preferred (Portney & Watkins, 2000), but due to the variable nature of the construct being measured in this case (discomfort), an ICC of 0.80 or higher was selected *a priori* to be evidence of good reliability for the WcS-DAT (Dworkin & Whitney, 1992; Portney & Watkins, 2000).

Cronbach's Alpha (α) was used to measure the internal consistency of the items within each of these scales. Internal consistency reflects the correlation among all items in a particular measurement instrument. Although the possible range of values is 0.00 to 1.00, the preferred range is 0.70 to 0.90 which suggests internal consistency without redundancy (Dworkin & Whitney, 1992; Portney & Watkins, 2000).

Correlations between the two parts of the WcS-DAT, the WcS-DAT and Chair Evaluation Checklist (CEC), and the WcS-DAT and the Short Form McGill Pain Questionnaire (SF-MPQ) were also analyzed using the Pearson product-moment correlation. By correlating the results of the WcS-DAT to the established CEC and SF-MPQ ratings it is possible to establish concurrent validity of the WcS-DAT, even though the latter is designed for a slightly different intent. The WcS-DAT is a measure of wheelchair seating discomfort that should correlate with both the SF-MPQ and the discomfort assessment portion of the CEC – also a measure of seat discomfort, but used in unimpaired populations.

5.3 RESULTS

One of the participants (diagnosis of ALS) recruited for this research became unavailable, due to an illness, prior to beginning data collection. In total, 29 participants entered this research study and 28 completed all four questionnaire sets, one individual was lost to follow up (diagnosis of MD) after completing only the first of the four questionnaire sets.

Each of the discomfort scales of the WcS-DAT were analyzed during this process. The General Discomfort Score (GDS) is based on 13 items all related to feelings of comfort or discomfort while sitting in a wheelchair. Each item is scored on a 7-point Likert scale and then all 13 scores are summed to obtain the GDS. The Discomfort Intensity Score (DIS) is the sum of 9 scores – eight individual body areas and one overall or general discomfort intensity score. Reliability of the chair evaluation checklist (CEC) and the Short Form of the McGill Pain Questionnaire (SF-MPQ) were also calculated.

ICC (2,*k*) scores were calculated to determine the reliability of the instruments in multiple combinations of test pairs. These included the one-hour intervals (tests 1+2 and tests 3+4) as well as the one-week intervals (tests 1+3 and tests 2+4). In addition, for the GDS and DIS scores, tests one and three were combined into a large group of "pre-tests" and tests two and four were combined into "post-tests" and the pretest-posttest ICC was calculated. ICC scores ranged from a low of 0.83 to a high of 0.97. All scores for the DIS and GDS met the established criteria of greater than 0.80, indicating acceptable levels of reliability. See Table 5-1 for specific ICC scores from these analyses.

Table 5-1: Test-retest reliability scores from WcS-DAT, CEC, and SF-MPQ

Test name	[a]Test #	[b]Retest #	n	ICC(2,*k*) score
GDS scale of WcS-DAT	1	2	17	0.92[c]
GDS scale of WcS-DAT	3	4	24	0.83[c]
GDS scale of WcS-DAT	1 and 3 (all tests)	2 and 4 (all re-tests)	41	0.86[c]
GDS scale of WcS-DAT	1	3	20	0.89[d]
GDS scale of WcS-DAT	2	4	20	0.87[d]
DIS scale of WcS-DAT	1	2	23	0.97[c]
DIS scale of WcS-DAT	3	4	25	0.95[c]
DIS scale of WcS-DAT	1	3	24	0.97[d]
DIS scale of WcS-DAT	2	4	22	0.95[d]
CEC, Part 1 (items 1 - 7)	1	2	26	0.90[c]
CEC, Part 1 (items 1 - 7)	3	4	26	0.93[c]
CEC, Part 2 (items 8 – 14)	1	2	27	0.91[c]
CEC, Part 2 (items 8 – 14)	3	4	27	0.88[c]
SF-MPQ, Items 1-15	1	2	26	0.95[c]
SF-MPG, Items 1-15	3	4	22	0.95[c]

[a] #1 = first administration, week 1; #2 = second administration, week 1
[b] #3 = first administration, week 2; #4 = second administration, week 2
[c] One-hour intervals
[d] One-week intervals

Internal consistency was assessed using Cronbach's alpha. These analyses were only used for the two parts of the WcS-DAT to determine if there were redundant items that needed to be removed from the tool. Cronbach's alpha (α) scores for the GDS portion of the WcS-DAT ranged from 0.89 to 0.92. DIS alpha scores ranged from 0.82 to 0.91. These scores show good internal consistency of the items involved without indicating redundancy within the measures. See Table 5-2 for specific results of the internal consistency testing.

Table 5-2: Internal consistency of items in the WcS-DAT

Scale	[a]Test #	n	Standardized Item Alpha (α)
GDS scale of WcS-DAT	1	21	0.91
GDS scale of WcS-DAT	2	23	0.92
GDS scale of WcS-DAT	3	27	0.89
GDS scale of WcS-DAT	4	24	0.89
DIS scale of WcS-DAT	1	25	0.82
DIS scale of WcS-DAT	2	24	0.86
DIS scale of WcS-DAT	3	27	0.91
DIS scale of WcS-DAT	4	25	0.91

[a] #1 = first administration, week 1; #2 = second administration, week 1
#3 = first administration, week 2; #4 = second administration, week 2

Pearson product-moment correlations were used to evaluate the relationships between the new measures of seating discomfort (the GDS and the DIS) and existing similar measures – including the Chair Evaluation Checklist (CEC) and the Short Form of the McGill Pain Questionnaire (SF-MPQ). The CEC is divided into two parts – the first 7 items measure

discomfort and the last 7 items measure comfort. The SF-MPQ is divided into three scores – the sum of the 15 pain-related questions, the pain visual analog scale (VAS) and the present pain intensity score (PPI). The final three of the 15 questions on the SF-MPQ relate specifically to the affective component of pain, therefore items 1 – 15 and 1 – 12 were analyzed separately

Each of these scores was analyzed for correlation with each of the two parts of the WcS-DAT. The two parts of the WcS-DAT (GDS and DIS) were also evaluated for their correlation with each other, as they measure two aspects of seat discomfort. These analyses were completed for each of the four administrations of the questionnaire sets. Correlation coefficients ranged from a low of -0.024 correlation between the comfort score of the CEC and the GDS score of the WcS-DAT, to a high of 0.932 correlation between the visual analogue portion of the SF-MPQ and the DIS scale of the WcS-DAT. Out of 52 separate correlations assessed, 45 of them were significant at the 0.001 level, six were significant at the 0.01 level and one was significant at the 0.05 level. These measures indicate good concurrent validity of the new measure with these already established measures. Details of the correlations are presented in Table 5-3.

Table 5-3: Correlations between discomfort measurement tools

Discomfort measurement tool/scale	Test #	n	Correlation with GDS scale	Correlation with DIS scale
DIS	1	19	0.719 [a]	--
DIS	2	20	0.593 [b]	--
DIS	3	26	0.794 [a]	--
DIS	4	22	0.817 [a]	--
CEC, Items 1 – 7 (discomfort)	1	21	0.716 [a]	0.795 [a]
CEC, Items 1 – 7 (discomfort)	2	22	0.783 [a]	0.818 [a]
CEC, Items 1 – 7 (discomfort)	3	27	0.820 [a]	0.907 [a]
CEC, Items 1 – 7 (discomfort)	4	23	0.794 [a]	0.917 [a]
CEC, Items 8 – 14 (comfort)	1	21	-0.531 [b]	-0.551 [b]
CEC, Items 8 – 14 (comfort)	2	23	-0.024 [c]	-0.529 [b]
CEC, Items 8 – 14 (comfort)	3	27	-0.680 [a]	-0.709 [a]
CEC, Items 8 – 14 (comfort)	4	24	-0.582 [b]	-0.593 [b]
SF-MPQ (Q1-15)	1	21	0.742 [a]	0.849 [a]
SF-MPQ (Q1-15)	2	23	0.770 [a]	0.867 [a]
SF-MPQ (Q1-15)	3	24	0.826 [a]	0.853 [a]
SF-MPQ (Q1-15)	4	22	0.714 [a]	0.763 [a]
SF-MPQ (Q1-12)	1	21	0.770 [a]	0.856 [a]
SF-MPQ (Q1-12)	2	23	0.797 [a]	0.865 [a]
SF-MPQ (Q1-12)	3	25	0.846 [a]	0.863 [a]
SF-MPQ (Q1-12)	4	22	0.718 [a]	0.774 [a]
SF-MPQ VAS	1	20	0.720 [a]	0.897 [a]
SF-MPQ VAS	2	18	0.852 [a]	0.845 [a]
SF-MPQ VAS	3	23	0.849 [a]	0.914 [a]
SF-MPQ VAS	4	18	0.832 [a]	0.932 [a]
SF-MPQ PPI	1	20	0.705 [a]	0.752 [a]
SF-MPQ PPI	2	22	0.767 [a]	0.703 [a]
SF-MPQ PPI	3	24	0.786 [a]	0.847 [a]
SF-MPQ PPI	4	21	0.710 [a]	0.800 [a]

[a] $p < .001$
[b] $p < .01$
[c] $p < .05$

5.4 DISCUSSION

Measurement of a construct such as discomfort, which can change rapidly, is challenging. Yet, the data show that the WcS-DAT is a highly stable and reliable measure of seating discomfort for individuals who have sensation and are long-duration wheelchair users (i.e. those who sit for more than 8 hours per day). Both the reliability of the WcS-DAT as a whole and the internal consistency of the individual items contained within it met or exceeded the predetermined targets for indicating reliable and consistent performance. Due to these positive results, no changes in the content of the WcS-DAT were necessary. The WcS-DAT was shown to allow sensate long duration wheelchair users to reliably quantify their levels of sitting discomfort.

Our data also established the concurrent validity of the WcS-DAT without duplicating the criterion tools. The high correlations found with previously established measures, such as the Chair Evaluation Checklist (CEC) and the Short Form of the McGill Pain Questionnaire (SF-MPQ) indicated good concurrent validity of the WcS-DAT. These relationships confirm that the WcS-DAT measures what it was designed to measure – wheelchair seat discomfort. Moreover, the correlations were not so high as to indicate that the WcS-DAT duplicated the CEC or SF-MPQ, or so low that as to suggest that the CEC or SF-MPQ may have more adequately quantified wheelchair seat discomfort. Similarly, the correlations between the two major parts of the WcS-DAT, the GDS and the DIS, confirmed measurement of associated constructs without redundancy.

The goal of keeping the WcS-DAT short enough to make it realistic for use in research and in clinical practice, while still developing a stable and reliable tool, was also met. The WcS-DAT is a three-part tool with approximately 31 total items, most of which require a yes/no

response or a numeric response. Participants reported completing the WcS-DAT in 5 minutes once they became familiar with the format. This tool was self-administered with the exception of the first administration and participants reported little difficulty understanding or responding to any of the items. Some formatting modifications were suggested to prevent some of the more common errors in recording results. Even participants without the ability to manually record the responses themselves had little difficulty communicating the results to an assistant. This was true even when an alternative communication device was used. Ease of administration is requisite for a tool to be useful in a clinical setting in which many different levels of communication are common.

Our findings must also be considered with the limitations of the study in mind. First, the participants were not randomly selected. Participants volunteered for the study after seeing advertisements or hearing of the study from a third party. However, there is no evidence that this sample is not representative of sensate, long-duration wheelchair users. Second, when completing duplicate assessments within a one-hour interval, the potential for carry over effects exists. This could not be avoided, as the interval between assessments needed to be short enough so that a significant change in discomfort itself would not have occurred. This risk of carryover was minimized by the complexity of the entire questionnaire packet (i.e. the presence of multiple tools) and the intervening activities of the participants. Also, judging from the similarity of the one-hour interval result and the one-week interval results, there is no indication that carryover effects were a detriment to the reliability of the study. Thirdly, the inclusion of only sensate wheelchair users with severe motor impairment limits the generalizability of these results to other groups of wheelchair users. Reliability testing with wheelchair users with different characteristics may yield different results than those presented in this study.

Future research with the WcS-DAT will include an examination of the sensitivity of the tool and an analysis of its reliability and validity among wheelchair users with different impairments or levels of sensory and motor abilities than those in the current study. The WcS-DAT should also be examined for measuring discomfort in situations where change in discomfort levels is expected – either due to the passage of time, or to the introduction of different seating surfaces or components.

In summary, the evidence supports the use of the WcS-DAT as a robust measurement tool for assessing seating discomfort in future research. This tool may also be valuable as a clinical outcome measures for assessing discomfort following provision of seating interventions with the goal of reducing or eliminating discomfort.

6.0 EFFICACY OF THE WCS-DAT IN SINGLE SUBJECT RESEARCH OF WHEELCHAIR SEAT DISCOMFORT

6.1 INTRODUCTION

The purpose of this study was to examine the effectiveness of the Wheelchair Seating Discomfort Assessment Tool (WcS-DAT) for quantifying discomfort over time by eliciting the comfort-discomfort continuum using alternative seating equipment. In addition, a test wheelchair introducing new user-adjustable seating was tested for its effectiveness at relieving discomfort for the participants. New techniques for studying wheelchair-seating discomfort were examined to guide future research in this important aspect of wheelchair seating outcomes.

People who use wheelchairs, particularly those who sit for more than 8 hours per day, often experience discomfort (Scherer, 1996b; Shaw & Taylor, 1991; Weiss-Lambrou et al., 1999). Discomfort leads to negative consumer satisfaction (Weiss-Lambrou et al., 1999), decreased quality of life (Herzberg, 1993), problems related to wheelchair propulsion ergonomics (DiGiovine et al., 2000), and adoption of poor sitting postures to relieve discomfort (Engstrom, 2002) -- all of which may impair everyday function and the ability to remain seated in a wheelchair (Crane & Hobson, 2002). Yet few researchers have investigated the nature and causes of wheelchair seat discomfort, or possible solutions to this problem (Monette et al., 1999; Shaw, 1992).

The Wheelchair Seating Discomfort Assessment Tool (WcS-DAT) was developed using long-term wheelchair users' feedback about wheelchair-seating-related discomfort (Brosh & Arcan, 2000). There are two discomfort-related scores associated with the WcS-DAT. The General Discomfort Assessment (GDA) – contains eight statements related to discomfort and five statements related to comfort that are rated on a 7-point Likert scale. The responses are coded on a scale of 1 – 7, with 1 indicating maximum comfort and 7 indicating maximum discomfort, and then all individual item scores are summed to form the GDA score. The Discomfort Intensity Score (DIS) - combines seven specified body areas (back, neck, buttocks, legs, arms, feet, and hands), which are rated for degree of discomfort intensity on a 0 to 10 scale (0 = no discomfort, 10 = maximum discomfort), with one optional body area that the rater may identify, as well as a general discomfort intensity rated on the same 0 to 10 scale. During the coding process, each score is increased by one, to eliminate zero scores for data analysis, resulting in a final score range of 1 to 11. As with the GDA score, these 9 item scores are summed to arrive at a DIS score.

The reliability and validity of the WcS-DAT have been established (Crane, Holm, & Hobson, 2003), but its effectiveness in showing changes in levels of discomfort over time or with the introduction of novel wheelchair seating has not been established. To be an effective outcome measure of wheelchair seating discomfort, this tool must be capable of reflecting changes in actual discomfort levels of wheelchair users, as would be expected with increased sitting duration and with changes in wheelchair seating equipment. Moreover, consistent methodology for examining discomfort among long duration wheelchair users has not been established and this study examined the effectiveness of a single subject research design as a methodology to evaluate this serious and prevalent problem.

6.2 METHODS

6.2.1 Participants

A convenience sample of six wheelchair users was initially recruited from the greater Pittsburgh area. The participants all reported using powered wheelchairs for a minimum duration of 8 hours per day. All had severe motor impairment and intact sensation on their buttocks and lower extremities and experienced discomfort associated with sitting in their wheelchairs. None of the participants had experienced skin breakdown on their seating surfaces (buttocks or posterior thighs) within the year prior to enrollment. Of the original six recruited participants, only four completed the full trial. One individual withdrew following 2-weeks of testing and another withdrew prior to commencing testing. One of these six participants completed two trials – one with each test wheelchair design; he will be designated as participants "1" and "1a." to reflect the results of both of these separate trials. Due to the loss of two participants, one additional participant was recruited for the study for a total of seven participants recruited and six complete trials. See Table 6-1 for participant descriptions and study design used.

Table 6-1: Participant diagnosis and study design assignment

Participant	Diagnosis	Gender	Study Design	Result
1	MD	Male	A1 C1 A2	Partial TestChair1 trial
1a	MD	Male	A1 C2 B2 A2	Complete TestChair2 trial
2	MS	Male	A1 B1 B2 C2 A2	Partial TestChair1 trial and complete TestChair2 trial
3	MS	Male	A1 C2 B2 A2	Complete TestChair2 trial
4	MS	Male	A1 B2 C2 A2	Complete TestChair2 trial
5	ALS	Female	A1 C2 B2 A2	Complete TestChair2 trial
6	MS	Male	A1 B2 C2 A2	Withdrew following 2 weeks
7	MD	Male	A1 C2 B2 A2	Withdrew prior to testing

MD = Muscular dystrophy

MS = Multiple sclerosis

ALS = Amyotrophic lateral sclerosis

6.2.2 Design

A single subject, multiple baseline, alternating treatment design was used to conduct the testing of the WcS-DAT and the user adjustable test wheelchair. The study was conducted to assess changes in sitting discomfort levels across several alternating phases consisting of different baseline or intervention conditions (see Table 6-2 for summary):

1. Phase A1: (Baseline, Condition 1) Participant seated in his or her own wheelchair using his or her seating system.
2. Phase B1: (Intervention, Condition 2) Participant seated in the first design of the test wheelchair (TestChair1) with features consisting of powered seat tilt, powered back recline, and powered elevating leg rests (FeatureSet1).

3. Phase C1: (Intervention, Condition 3) Participant seated TestChair1 with features consisting of powered seat tilt, powered back recline, powered elevating leg rests and powered pneumatic air bladders embedded in contoured foam seat (4 bladders) and back (3 bladders) supports (FeatureSet2).
4. Phase B2: (Intervention, Condition 4) Participant seated in the second design of the test wheelchair (TestChair2) with FeatureSet1. TestChair2 differed from TestChair1 in that the seat cushion was no longer made primarily of foam, but was replaced with a 4 inch thick, air filled cushion.
5. Phase C2: (Intervention, Condition 5) Participant seated in the TestChair2 with FeatureSet2 – 3 pneumatic bladders embedded in the foam back cushion and the ability to control the inflation levels of each of the four quadrants of the air filled seat cushion.
6. Phase A2 (Return to baseline, Condition 6) Participant seated in his or her own wheelchair using his or her seating system.

Participants were randomly assigned to one of two alternating designs – ABCA or ACBA to control for possible order effects of the intervention conditions (phases B1, B2, C1, and C2) involving the different test chair features.

Table 6-2: Conditions involved in this research

Condition	Condition number	Wheelchair	Feature set	Phase Designation
Baseline	1	Participant's own	NA	A1
Intervention	2	TestChair1	FeatureSet1	B1
Intervention	3	TestChair1	FeatureSet2	C1
Intervention	4	TestChair2	FeatureSet1	B2
Intervention	5	TestChair2	FeatureSet2	C2
Return to baseline	6	Participant's own	NA	A2

6.2.3 Baseline Measures

Three baseline measures were used to assess wheelchair-seating discomfort. These were: (1) time in chair (TIC) or total sitting time per day; (2) the GDA score of the WcS-DAT for each 4-hour sitting period; and (3) the DIS score of the WcS-DAT for each 4-hour sitting period. For each condition, seven days of data collection with the three baseline measures yielded a maximum of 28 days of testing per trial (with the exception of participant 2, who completed more than 28 total days).

6.2.3.1 Time in Chair (TIC)

The first baseline measure used to assess wheelchair-seating discomfort in sensate wheelchair users was total sitting time per day (TIC). This measure consisted of the total amount of time spent seated in either the participant's own wheelchair (phases A1 and A2) or a combined total

of time spent sitting in the relevant test wheelchair and the participant's own wheelchair (phases B1, B2, C1, C2). This combined sitting time was necessary as participants 1 and 2 were unable to exclusively use either test chair during conditions 2 – 5 due to problems unrelated to sitting discomfort. As this measure was a once per day measure, there was a maximum of seven data points per condition for each participant.

6.2.3.2 GDA score

The second baseline measure, the GDA score, is the first discomfort score obtained from the WcS-DAT. The GDA score has a possible range of 13 – 91, with higher scores representing increased levels of discomfort. This measure is recorded for each 4-hour period of time spent sitting. Based on an 8 – 12 hour sitting day, the typical number of data points for this measure was 14 (2 times per day) to 21 (3 times per day) points per condition.

6.2.3.3 DIS score

Baseline measure three, the DIS score, is the second discomfort score obtained from the WcS-DAT. This score has a possible range of 8 – 99. A score of 8 indicates no discomfort in any part of the body and a score of 99 indicates a maximum amount of discomfort in 8 body areas and in the body as a whole. This measure is recorded with the same frequency as the GDA scores.

6.2.4 Data collection

Prior to participation in this study, all participants signed informed consent documents as per the study protocol approved by the University of Pittsburgh's institutional review board. For the baseline measures discussed previously, participants completed daily logs and WcS-DAT questionnaires. The logs enabled participants to easily record their daily sitting schedule, allowing tabulation of the number of total hours spent sitting each day. Each participant was

provided with a notebook for each week of participation in the study. The notebook contained data collection forms for 7 days, including for each day: a daily log sheet, 5 copies of the WcS-DAT – each in a different color (enough for up to 20 hours of sitting per day), a page on which to record comments or questions, a form prompting the participant to compare the current day with an average day experienced over the past three months, and a checklist to determine if all necessary paperwork had been completed for that day. The researcher contacted each participant several times per week to answer any questions and clarify procedures as needed. Participants were also encouraged to call or page the researcher if there were any problems or question regarding either the documentation or the test wheelchair. The researcher visited with each participant weekly to transition the participant from one condition to the next and to collect data and provide the following week's notebook.

6.2.5 Analysis

Both traditional graphic visual analyses (Ottenbacher, 1986) and specialized semi-statistical and statistical procedures designed for use in single subject design (Franklin, Allison, & Gorman, 1996; Ottenbacher, 1986), were used to analyze the effectiveness of the TIC data and the GDA and DIS scores for measuring change in sitting discomfort. All discomfort-related data were manually entered into an SPSS data file and then summary data were transferred into a Microsoft Excel spread sheet, and graphs were developed for performing visual analysis. Semi-statistical and statistical procedures used included: tests for serial dependency using Bartlett's test of the lag-1 autocorrelation coefficients (Ottenbacher, 1986), celeration line analyses, two-standard deviation band analyses (Ottenbacher, 1986), and Tryon's C-Statistic (Tryon, 1982).

Prior to any visual or statistical analysis, Bartlett's test of the lag-1 autocorrelation coefficients was performed on each phase of data collected for each participant. This is a conservative approach for determining the degree of serial dependency of the data, with a significant result for any individual phase causing all data for that participant to be treated as serially dependent (Ottenbacher, 1986). When serial dependency of the data was found, the C Statistic alone was relied on for indications of a significant intervention effect, as the C Statistic may be applied to data that are serially dependent (Tryon, 1982).

Following the autocorrelation testing, a hierarchical approach to data analysis was undertaken. The data were assessed for significant inter-phase differences using four approaches with increasing levels of statistical rigor. Analysis began with a basic visual inspection of the data, which is the hallmark of single subject research analysis (Kazdin, 1982). Following this basic visual inspection, semi statistical and statistical methods developed specifically for enhanced single subject data analysis were employed. The celeration line analysis is the most basic of these semi statistical approaches, followed by a two standard deviation band analysis and finally a C-Statistic analysis – the highest level of statistical rigor used in this single subject data analysis and a method that is acceptable for use with serially dependent data (Tryon, 1982).

For visual analysis, data were plotted and phase transitions were marked with a vertical line dividing each phase. Mean lines were then added as horizontal lines passing through the mean for each phase data set. In addition, trend lines for each data set were added to the graphed data for comparison purposes. Finally, these data were inspected and a judgment was made as to whether the mean or trend of the data differed across phases.

The celeration line, or split middle, procedure was used as a semi-statistical enhancement of the data to determine the presence of a significant difference in a dependent variable across phases. For the celeration line analysis, graphed data were enhanced by the addition of a baseline trend line. This trend line was then extended into the subsequent conditions as a celeration line (graphed as a dashed line to represent the expected trend if no intervention were initiated) and the ratio of points above or below the celeration line was used in conjunction with Bloom's probability table (Ottenbacher, 1986) to determine the presence of a significant difference in the dependent variable across phases at the $p < 0.05$ level (one tailed).

Following the celeration line analysis, another semi statistical procedure with an even higher degree of scientific rigor was used. This was the two standard deviation band method. For the two standard deviation band procedure, the mean of the data points for a selected baseline or intervention phase (depending on the particular phase to phase comparison required) was plotted as a horizontal line and extended across subsequent phases. Two dashed horizontal lines were then added, one each at two standard deviations above the mean and two standard deviations below the mean. In order for one condition to be deemed significantly different from another at the $p < 0.05$ level (one tailed), there must be two consecutive data points outside the relevant two standard deviation band (Ottenbacher, 1986).

The final statistical analysis method used, and the one with the highest degree of scientific and statistical rigor, was the C Statistic method described by (Tryon, 1982). The C Statistic is a modified time series analysis methodology designed to evaluate treatment interventions with small data sets derived from single subject research designs (Tryon, 1982). As described by Tryon, the C Statistic was first calculated for the data within one phase. Following this, data were combined from phases as needed for comparison between phases. If

the data within any phase resulted in a non-significant Z score ($Z < 1.64$), then the combined data of the two phases requiring comparison were assessed for level of significance. If, however, the Z score for the data within any phase was found to be significant ($Z \geq 1.64$), this was an indication of a significant trend in the baseline data. If this occurred, the analysis of the baseline and intervention phase data was accomplished using a comparison series – a less powerful approach, but necessary in the presence of a significant baseline trend (Tryon, 1982). This comparison series was generated by subtracting the baseline values from the treatment values until all values were used. This comparison series was then tested for significance using the same C Statistic analysis.

6.3 RESULTS

Results from subject testing under each of the stated conditions have been included to demonstrate the effectiveness of the WcS-DAT, the methodology used in testing, and the user adjustable seating introduced. Results have been organized according to the associated baseline measure to demonstrate the effectiveness of the measure and the adjustable seating across subjects. Means and standard deviations for all baseline measures, all participants, and all conditions are presented in Table 6-3.

Table 6-3: Means and standard deviations of discomfort measures of each participant

TIME IN WHEELCHAIR						
	Condition (Phase)					
Participant	1 (A1)	2 (B1)	3 (C1)	4 (B2)	5 (C2)	6 (A2)
1	10.4 (2.7)	NA	10.2 (2.6)	NA	NA	9.9 (2.5)
1a	8.9 (1.7)	NA	NA	9.5 (0.6)	8.4 (2.5)	8.1 (1.1)
2	11.7 (0.6)	11.8 (2.8)	NA	11.6 (1.2)	11.8 (1.2)	12.4 (0.6)
3	11.9 (1.3)	NA	NA	12.0 (2.3)	12.6 (1.2)	12.5 (3.2)
4	8.7 (0.8)	NA	NA	7.9 (1.2)	7.4 (1.2)	7.9 (0.9)
5	7.9 (1.4)	NA	NA	8.1 (0.9)	7.9 (1.0)	7.9 (0.2)
GDA SCORE						
	Condition (Phase)					
Participant	1 (A1)	2 (B1)	3 (C1)	4 (B2)	5 (C2)	6 (A2)
1	57.1 (6.4)	NA	52.7 (4.2)	NA	NA	49.6 (4.8)
1a	50.2 (3.0)	NA	NA	49.5 (2.2)	50.0 (3.2)	51.7 (1.9)
2	39.6 (9.3)	54.4 (3.9)	NA	36.0 (8.8)	43.6 (10.2)	40.1 (10.4)
3	58.3 (9.8)	NA	NA	28.8 (1.2)	28.9 (4.1)	62.3 (13.1)
4	52.8 (10.5)	NA	NA	56.0 (10.2)	59.6 (9.0)	49.5 (2.9)
5	60.9 (4.1)	NA	NA	57.7 (2.7)	50.1 (8.5)	60.5 (3.5)
DIS SCORE						
	Condition (Phase)					
Participant	1 (A1)	2 (B1)	3 (C1)	4 (B2)	5 (C2)	6 (A2)
1	33.8 (5.1)	NA	27.4 (2.8)	NA	NA	24.9 (1.9)
1a	21.4 (1.6)	NA	NA	19.5 (1.0)	21.3 (2.1)	20.6 (1.2)
2	12.7 (1.0)	14.8 (1.3)	NA	12.5 (1.4)	12.9 (0.2)	12.9 (0.9)
3	36.7 (8.8)	NA	NA	9.8 (2.2)	15.5 (5.5)	21.5 (8.0)
4	16.8 (4.8)	NA	NA	20.3 (3.9)	21.9 (4.8)	15.5 (1.3)
5	45.3 (2.1)	NA	NA	47.1 (3.8)	33.4 (6.5)	51.2 (6.7)

6.3.1 Time in chair baseline

Results of the Bartlett test indicated no significant degree of autocorrelation for any of the subjects across any of the conditions. A summary of all autocorrelation testing may be found in Table 6-4. A summary of all of the TIC analysis results is presented at the conclusion of all of the time in chair results in Table 6-5.

Table 6-4: Autocorrelation test results for the time in chair (TIC) measure

Participant/ test phase	Autocorrelation Coefficient (r)	Bartlett's Test	Autocorrelated?
Participant 1:			
A1	0.2463	0.7559	No
C1	0.2524	0.8944	No
A2	0.1566	0.7559	No
Participant 1a:			
A1	0.3571	0.7559	No
B2	0.3750	0.7559	No
C2	0.3700	0.7559	No
A2	0.4263	0.7559	No
Participant. 2			
A1	0.1870	0.7559	No
B1	0.0018	1.1547	No
B2	0.3054	0.8165	No
C2	0.3902	0.8165	No
A2	0.4935	0.7559	No
Participant 3:			
A1	0.6943	0.7559	No
B2	0.3710	0.7559	No
C2	0.1595	0.7559	No
A2	0.1320	0.7559	No
Participant 4:			
A1	0.5863	0.7559	No
B2	0.1702	0.7559	No
C2	0.1118	0.7559	No
A2	0.2476	0.7559	No
Participant 5			
A1	0.4721	0.7559	No
B2	0.0693	0.7559	No
C2	0.1794	0.7559	No
A2	0.0238	0.7559	No

6.3.1.1 Participant 1

Phase A1: Baseline, Condition 1

For this baseline condition, Participant 1 used a Permobil Chairman powered wheelchair with a powered standing feature. His seating consisted of a Roho Quattro seat cushion and the standard Permobil contoured foam back cushion. He spent an average of 10.4 hours per day sitting in his wheelchair (standard deviation of 2.7 hours). There was a high degree of variability in these data and the trend line for this phase had a prominent negative slope (see Figure 6-1 for mean levels and trends). Participant 1 was randomized to an ACBA research design.

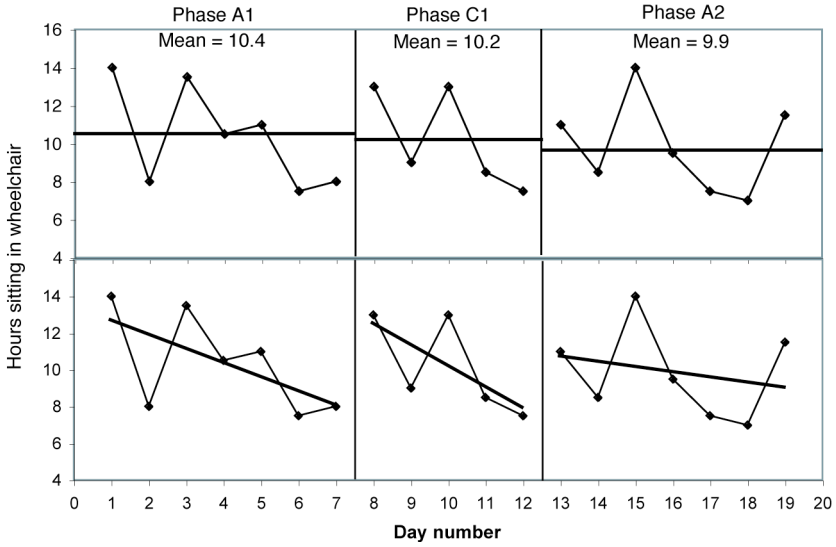


Figure 6-1: TIC means and trends for Participant 1

Phase C1: Intervention, Condition 3 (TestChair1, FeatureSet2)

During this intervention phase (C1), Participant 1 sat in TestChair1 an average of 10.2 hours per day with a standard deviation of 2.6 hours. Visual analysis of these data indicated no differences between phases A1 and C1 (see Figure 6-1) in either mean sitting duration or trend. For the Phase A1 (baseline) to Phase C1 (intervention) comparison, none of the results of the celeration line, two standard deviation band, or C Statistic ($Z = 0.69$) analyses were significant (see Figure 6-2), indicating no difference in sitting duration when using his own wheelchair or TestChair1. TestChair1 use was halted after 5 days due to development of redness under this participant's ischial tuberosity. This had been an established stopping point due to safety considerations. For this reason, this participant did not continue with Phase B1, but moved directly to the return to baseline phase (A2).

Phase A2: Return to baseline, Condition 6

Upon return to baseline, mean time sitting in his own wheelchair for Participant 1 was 9.9 hours per day ($SD = 2.5$ hours). Visual analysis indicated the persistence of great variability in this measure, but no difference in mean sitting duration from when he was sitting in TestChair1 and very little difference in the slope of the trend line (see Figure 6-1). As illustrated in Figure 6-2, celeration line testing of Phase A2 data using the Phase A1 trend line indicated a significantly greater sitting duration during Phase A2. Celeration line comparison of Phase C1 and Phase A2 also indicated a greater sitting duration when Participant 1 returned to using his own wheelchair than when he was using TestChair1. There were no significant findings from any of the two standard deviation band analyses, or for the C-Statistic analysis ($Z = 0.43$).

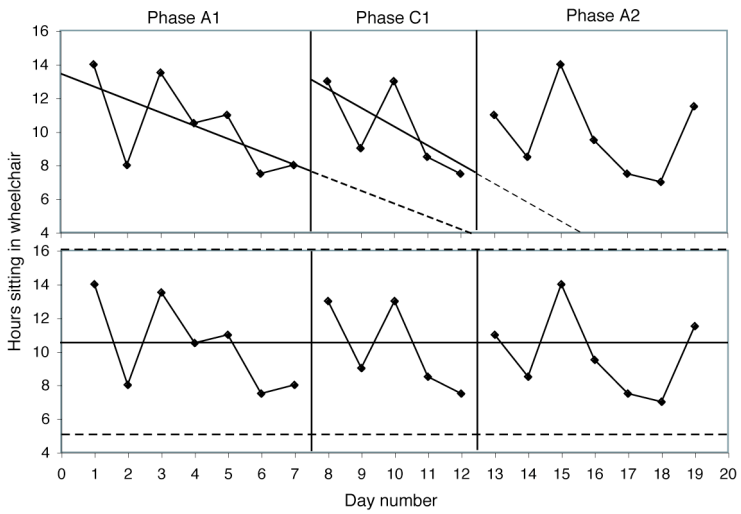


Figure 6-2: TIC celeration lines and two standard deviation bands for Participant 1

6.3.1.2 Participant 1a

Phase A1: Baseline, Condition 1

This participant used a different baseline wheelchair for this trial than that used during his first trial. His baseline wheelchair for this trial was a Permobil powered wheelchair with powered seat tilt and powered back recline systems. The seat cushion was a Roho Quattro air filled cushion and the back support cushion was a standard Permobil contoured foam back cushion. Mean sitting duration for this baseline phase was 8.9 hours per day with a standard deviation of 1.7 hours. These data were somewhat less variable than this participant's first trial, but still exhibited a downward sloping trend (see Figure 6-3). For this trial, Participant 1a was randomized to an ACBA design.

Phase C2: Intervention, Condition 5 (TestChair2, FeatureSet2)

Mean sitting duration in TestChair2 with FeatureSet2 was 8.4 hours with a standard deviation of 2.5 hours. Visual analysis of these data revealed no differences in mean sitting duration in TestChair2 compared to his own wheelchair. The trend lines do show a change in trend to an upward sloping trend line when using TestChair2. See Figure 6-3 for graphical illustration of means and trends for Participant 1a. Celeration line, two standard deviation band (see Figure 6-4), and C Statistic (Z = 0.07) analyses all indicated no significant difference in sitting duration between Phase A1 and Phase C2.

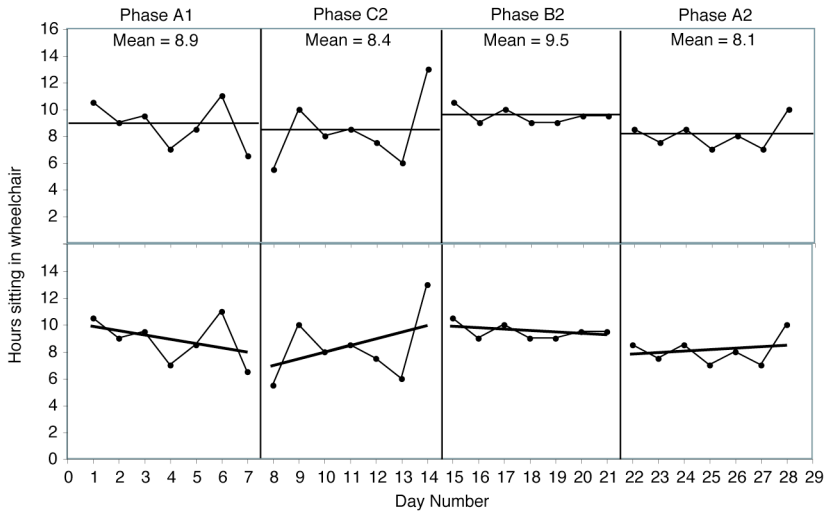


Figure 6-3: TIC means and trends for Participant 1a

Phase B2: Intervention, Condition 4 (TestChair2, FeatureSet1)

The mean time spent sitting in TestChair2 with FeatureSet1 (Phase B2) was 9.5 hours per day (SD = 0.6 hours). Visual analysis continued to reveal no mean sitting duration difference from the baseline (Phase A1) condition for this measure (see Figure 6-3), however the trend slope became slightly downward during this intervention phase, showing a change from the earlier intervention (Phase C2). Celeration line analysis of Phase B2 compared with Phase A1 indicated that Participant 1a tolerated a significantly greater sitting duration in TestChair2 than in his own wheelchair (see Figure 6-4), however the two standard deviation band test did not show a significant effect. The C-statistic test of Phase A1 and Phase B2 data confirmed the significant result found with the celeration line ($Z = 1.73$).

Visual comparison of mean durations between phases C2 and B2 (the two intervention phases) indicated only a slight change in average sitting duration, however inspection of the trends lines revealed a difference in slope from an upward slope for TestChair2 with FeatureSet2 to a slightly downward slope for TestChair2 with FeatureSet1 – indicating a decline in sitting duration when the traditional user adjustable feature set was in use. Celeration line comparison of sitting duration for Phase C2 and Phase B2 indicated a significantly lower sitting duration during Phase B2 (TestChair2 with FeatureSet1), but there was no significant difference detected by the two standard deviation band analysis (see Figure 6-4). The Z score from the C statistic test of the Phase B2 and Phase C2 data was also not significant ($Z = 0.15$).

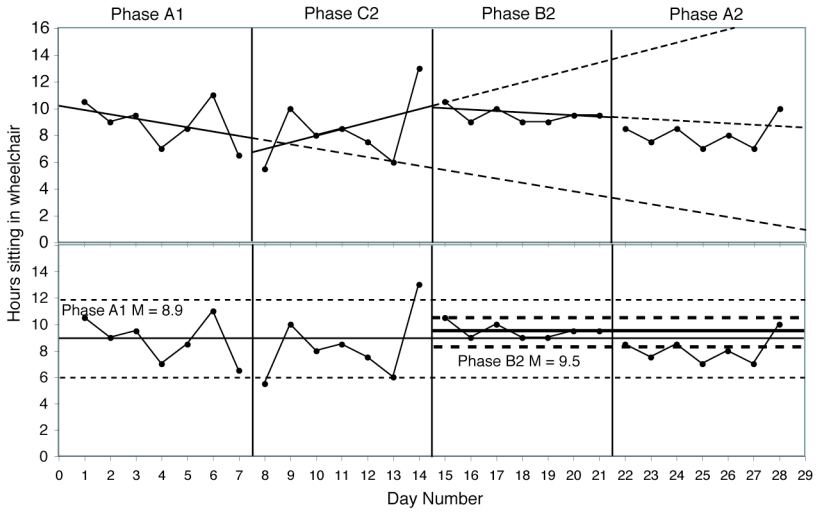


Figure 6-4: TIC celeration lines and two standard deviation bandsfor Participant 1a

(darker bands in lower frame are for B2 to A2 comparison)

Phase A2: Return to baseline, Condition 6

Upon returning to use of his own wheelchair, Participant 1a spent an average of 8.1 hours sitting per day (SD = 1.1 hours). Visual analysis did not indicate a difference in mean sitting duration between Phase A2 and the interventions, phases B2 and C2 (see Figure 6-3) or the original baseline phase (A1). The trend line for Phase A1 returned to a slightly positive slope, a change from the Phase B1 downward sloping trend. Celeration line and two standard deviation band analyses both indicated a significantly lower sitting duration when he returned to sitting in his own wheelchair compared with his sitting duration in TestChair2 with FeatureSet1 (Phase B2). In contrast, the C-statistic comparison of Phase B2 and Phase A2 data was not significant (Z = 1.39).

6.3.1.3 TestChair1 and TestChair2 comparison

For the first participant, additional analyses were performed based on his testing of both experimental wheelchairs. For these analyses, results from conditions 3 (Phase C1 from the first trial), 4 (Phase B2 from the second trial) and 5 (Phase C2 from the second trial) testing were analyzed to determine the presence of significant differences between TestChair1 and TestChair2. Visual comparison of Phase C1 (Participant 1, Condition 3) with Phase C2 (Participant 1a, Condition 5) revealed small differences in sitting duration means, but a reversal of trend slopes from a downward slope during Phase C1 to an upward slope during Phase C2 (see Figure 6-5).

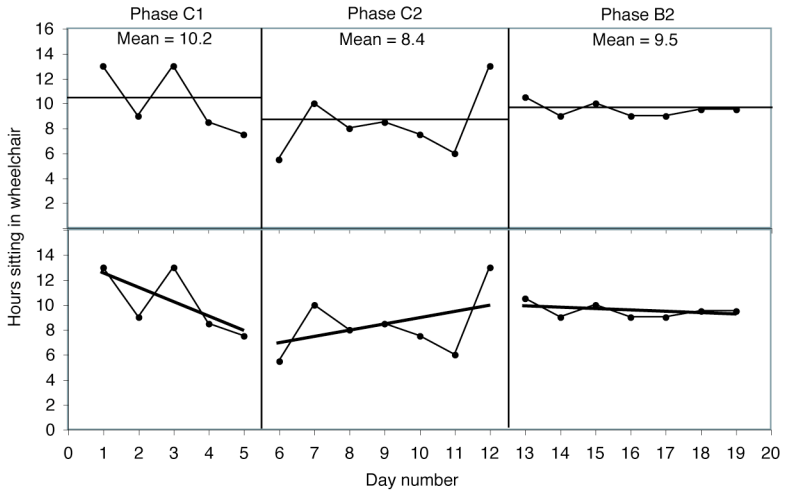


Figure 6-5: TIC means and trends - TestChair1 and TestChair2

The celeration line analyses indicated a significant increase in sitting duration from TestChair1 (Phase C1) to TestChair2 with either FeatureSet1 (Phase B2) or FeatureSet2 (Phase C2). The two standard deviation band results were not significant for either phase C1 to C2 or phase C1 to B2 comparisons (see Figure 6-6), nor were C statistic analyses (Z = 0.45 for C1 to C2; Z = 0.15 for C1 to B2).

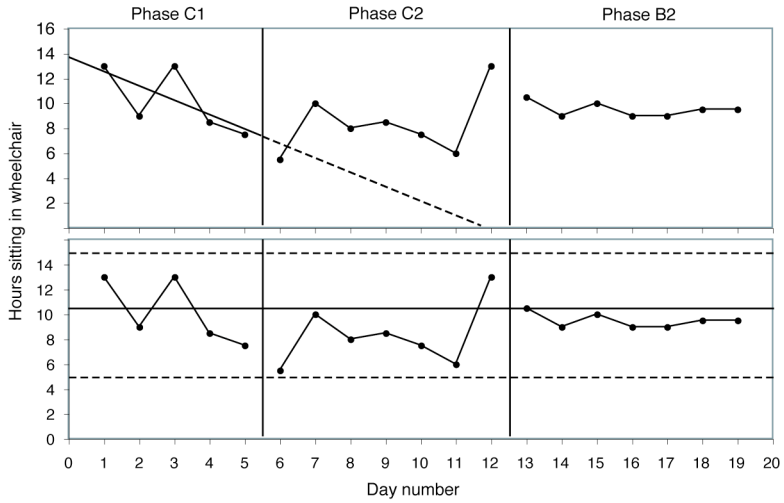


Figure 6-6: TIC celeration line and two standard deviation bands - TestChair1 and TestChair2

6.3.1.4 Participant 2

Phase A1: Baseline, Condition 1

Participant 2 spent an average of 11.7 hours (SD = 0.6 hours) per day seated in his own Permobil powered wheelchair with powered seat tilt, back recline, and powered elevating leg rests during this baseline phase (A1). His seating consisted of the standard Permobil contoured foam seat and back cushions on solid seat and back pans. His sitting schedule was quite consistent from day to day, leading to minimal variability. The trend line for these data had a slight positive slope (see Figure 6-7 for means and trends). This participant was randomized to an ABCA design. His TestChair1 trial was interrupted during Phase B1 and he moved to TestChair2 testing in Phase B2 upon his return.

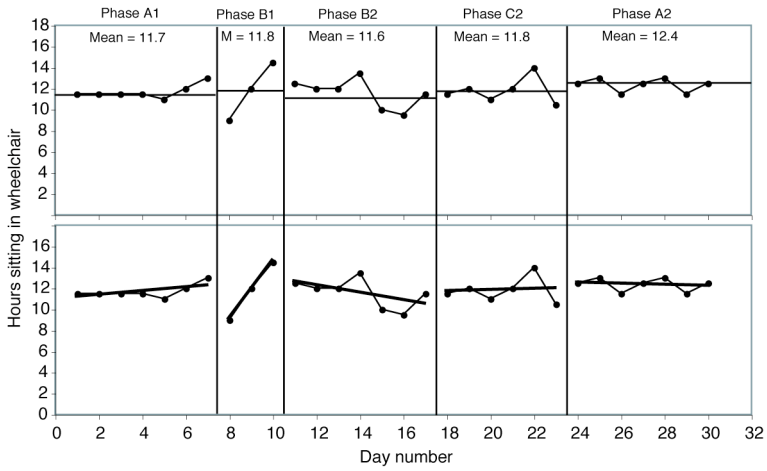


Figure 6-7: TIC means and trends for Participant 2.

Phase B1: Intervention, Condition 2 (TestChair1, FeatureSet1)

During Phase B1, Participant 2 sat in TestChair1 an average of 11.8 hours per day (SD = 2.8). Due to problems with discomfort and with functional use of TestChair1 in his environment, this phase was interrupted after 3 days to alter the test wheelchair. For this reason, there were only 3 TIC data points collected during this phase. Visual analysis of these data (presented in Figure 6-7) revealed no change in mean level from baseline (Phase A1), but a significant change in trend with an upward sloping trend during Phase B1 – caution must be applied with this inspection due to the small number of observations. There were not enough observations in Phase B1 for celeration line analysis and neither the two standard deviation band analysis nor the C Statistic ($Z = 0.17$) indicated any significant difference in sitting duration between Phase A1 and Phase B1.

Phase B2: Intervention, Condition 4 (TestChair2, FeatureSet1)

After construction of TestChair2, this trial was resumed with Participant 2. Mean sitting time in TestChair2 with FeatureSet1 was 11.6 hours (SD = 1.2). Visual analysis of graphed data revealed no change in mean duration from Phase A1, baseline, but the trend for Phase B2 had a slightly more negative slope. Celeration line comparison of Phase A1 and Phase B2 indicated a significantly lower sitting duration when Participant 2 was using TestChair2 compared with that in his own wheelchair. Neither the two standard deviation band nor the C Statistic ($Z = 0.98$) analysis indicated a significant difference in sitting duration between TestChair2 with FeatureSet1 and his own wheelchair.

Visual comparison of the sitting duration data from use of TestChair1 (Phase B1) and TestChair1 (Phase B2) indicated no difference in mean sitting duration, but the slopes of the two trend lines are quite different from each other. Celeration line analysis of Phase B2 data compared with that of Phase B1 indicated a significantly lower sitting duration when use of TestChair2 was initiated (Phase B2). Neither the two standard deviation band nor the C Statistic ($Z = 0.58$) analysis was significant.

Phase C2: Intervention, Condition 5 (TestChair2, FeatureSet2)

Mean sitting time in TestChair2 using FeatureSet2 (C2) was 11.8 hours (SD= 1.2 hours). Visual analysis of this data indicated no substantial difference in average sitting duration during this phase compared with previous phases (see Figure 6-7). The trend in the Phase C2 data was very similar to that found in the first baseline phase (A1). The celeration line analysis of Phase C2 data compared with Phase A1 data indicated a significantly lower sitting duration in TestChair2 compared with his baseline wheelchair. As with Phase B2, neither the two standard deviation band, nor the C Statistic ($Z = 0.67$) indicated any significant difference in sitting duration between TestChair2 and his own wheelchair.

To determine any sitting duration differences between use of FeatureSet1 and use of FeatureSet2, analysis of Phase B2 and Phase C2 data was undertaken. The mean sitting duration across these two phases did not differ. The trend of the Phase C2 data did change from a slightly negative slope found in Phase B2 to a slightly positive slope in Phase C2 (see Figure 6-7). Celeration line analysis of this data indicated a greater sitting tolerance in TestChair2 when using FeatureSet2 as opposed to that when using FeatureSet1 (see Figure 6-8). Neither the two standard deviation band nor the C Statistic ($Z = 0.99$) analysis confirmed this difference.

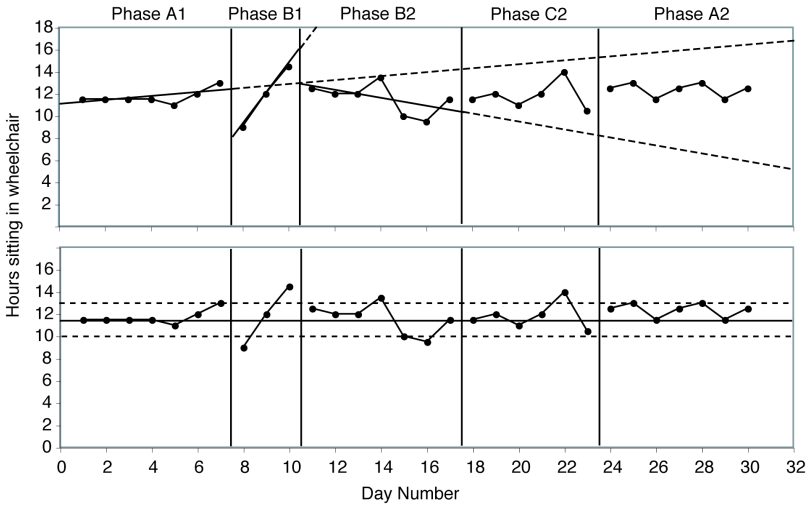


Figure 6-8: TIC celeration lines and two standard deviation bands for Participant 2.

Phase A2: Return to baseline, Condition 6

Mean sitting duration upon return to baseline was 12.4 hours (SD = 0.6 hours). Visual analysis revealed no differences in average sitting duration between Phase A2 and either of the intervention phases B2 and C2 (see Figure 6-7) or the first baseline phase (A1). Variability and trend of the sitting duration data during this phase (A2) closely resembled those found during the first baseline phase (A1). Celeration line comparison of the return to baseline data (Phase A2) and the original baseline data (Phase A1) indicated a significantly lower sitting duration upon return to baseline. Neither the two standard deviation band nor the C Statistic (Z = 0.96) analysis indicated this significant difference between sitting durations of the two baseline phases.

Comparison of the return to baseline phase (A2) to the final intervention phase (C2) was also carried out. Visual analysis of the data from these two phases indicated no differences in mean sitting duration or in trends for these data. Neither the celeration line nor the two standard deviation band analysis of phase C2 and A2 data was significant. Additionally, the C Statistic indicated no significant differences in sitting duration between these two phases (Z = 1.54).

6.3.1.5 Participant 3

Phase A1: Baseline, Condition 1

Participant 3 used a Pride Jazzy powered wheelchair with a van style seat system during his baseline phase (A1). The seating consisted of a solid seat pan with a contoured foam seat cushion (Invacare Infinity Seat with a visco-foam ischial insert), and a manually reclining contoured foam back support. Average sitting duration in this wheelchair was 11.9 hours (SD = 1.3 hours). The trend of these data had a steep positive slope (see Figure 6-9 for mean level and trend graphs). Participant 3 was randomized to an ACBA design.

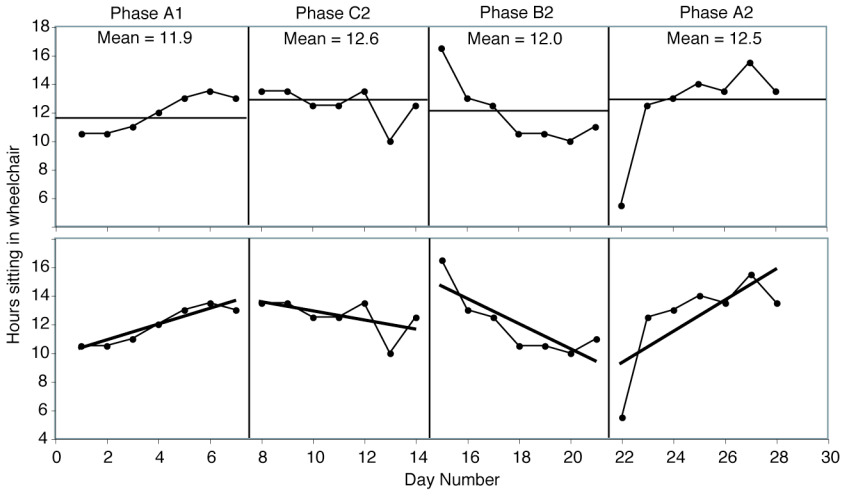


Figure 6-9: TIC means and trends for Participant 3.

Phase C2: Intervention, Condition 5 (TestChair2, FeatureSet2)

Mean sitting duration in TestChair2 using FeatureSet2 was 12.6 hours per day (SD = 1.2 hours). Visual analysis did not indicate any differences in mean sitting duration from Phase A1 to Phase C2 (see Figure 6-9), however there was a reversal in the direction of the trends for these two data sets. Celeration line analysis indicated a significantly lower sitting duration in TestChair2 compared with his own wheelchair (see Figure 6-10). The two standard deviation band analysis was not significant, but the C Statistic ($Z = 1.66$) indicated significantly less sitting time in TestChair2.

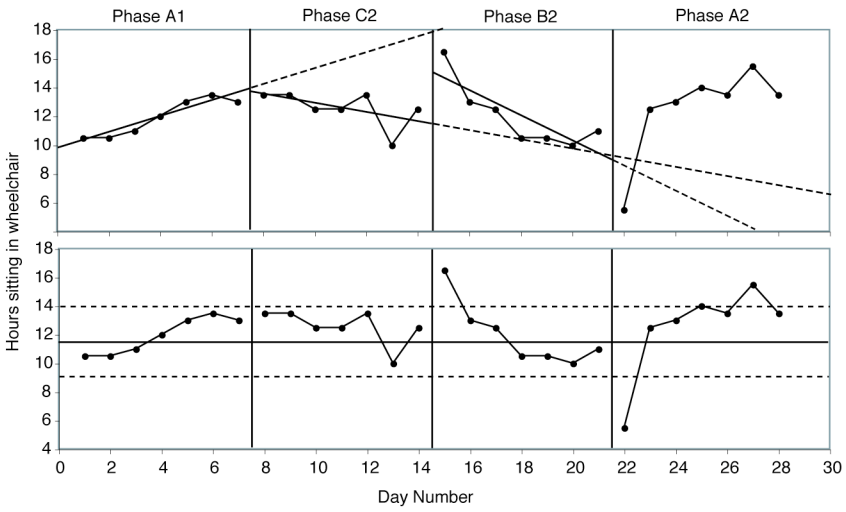


Figure 6-10: TIC celeration lines and two standard deviation bands for Participant 3.

Phase B2: Intervention, Condition 4 (TestChair2, FeatureSet1)

For Participant 3, the mean sitting duration in TestChair2 using FeatureSet1 was 12.0 hours per day (SD = 2.3 hours). Visual analysis of this data was complicated by increased data variability during this phase (Phase B2), but indicated no differences in mean sitting duration among any of the phases (A1, C2 or B2). The trend for the Phase B2 data had a prominent negative slope, more negative than that found during Phase C2 and a reversal of direction from Phase A1. The celeration line analysis of Phase B2 compared with Phase A1 indicated a significantly lower amount of sitting time using TestChair2 with FeatureSet1 than when using his own wheelchair. The two standard deviation band analysis of Phase A1 compared with Phase B2 indicated no significant differences in sitting duration, however, the C Statistic (Z = 4.92) indicated a significantly lower sitting duration in TestChair2 with FeatureSet1.

Visual comparison of the two intervention phases B2 and C2 revealed no mean sitting duration difference and little variation in trend with a slightly steeper slope exhibited by the Phase B2 data (see Figure 6-9). The celeration line analysis comparing these phases indicated a significantly higher sitting duration in TestChair2 when using FeatureSet1 compared that when using FeatureSet2 (see Figure 6-10), however the two standard deviation band analysis of these data was not significant. The C statistic (Z = 1.39) was also not significant, indicating no significant difference in sitting duration across intervention phases.

Phase A2: Return to baseline, Condition 6

Upon return to baseline, Participant 3 sat in his own wheelchair an average of 12.5 hours per day (SD = 3.2 hours). Visual analysis of these data compared with those of his final intervention phase (B2) indicated no difference in mean sitting duration, but the trend of the data contained a dramatic reversal in slope with a steep negative slope during Phase B2 and a steep positive slope during Phase A2. Celeration line analysis indicated a significantly higher sitting duration during in his own wheelchair compared with that in TestChair1 with FeatureSet1, however the more rigorous two standard deviation band analysis was not significant. The C Statistic (Z = 3.67) reconfirmed the celeration line result, indicating a significantly greater sitting duration in his own wheelchair.

Finally, comparison of the two baseline phases was performed. Visual inspection of the Phase A1 and Phase A2 data indicated a higher mean sitting duration during the second baseline phase, but the trends in the two data sets were quite similar. Celeration line comparison of these two phases indicated a significantly lower sitting duration during the second baseline phase (most likely attributable to the steep positive slope of the Phase A1 trend line). Neither the two standard deviation band, nor the C Statistic (Z = 0.80) indicated this difference.

6.3.1.6 Participant 4

Phase A1: Baseline, Condition 1

Participant 4 used a powered wheelchair base with a powered tilt seating system during his baseline phase. His seat and back cushions were made of contoured foam mounted on solid support structures. He also had a detachable, adjustable posterior head support. Mean sitting duration during this phase was 8.7 hours per day (SD = 0.8 hours). Participant 4 was randomized to an ABCA design.

Phase B2: Intervention, Condition 4 (TestChair2, FeatureSet1)

Mean sitting duration in TestChair2 with FeatureSet1 was 7.9 hours per day (SD = 1.2 hours). Visual analysis revealed no difference between Phase A1 and Phase B2 in mean sitting duration (see Figure 6-11), although there was a difference in the slope of the trend lines for these two phases, with a much steeper positive slope occurring when he was seated in TestChair2 (Phase B2). Celeration line analysis indicated a significantly lower sitting duration when using TestChair2 compared with that when he was using his own wheelchair (see Figure 6-12), however neither the two standard deviation band nor the C Statistic (Z = 0.02) analysis confirmed this difference in sitting duration between the two wheelchairs.

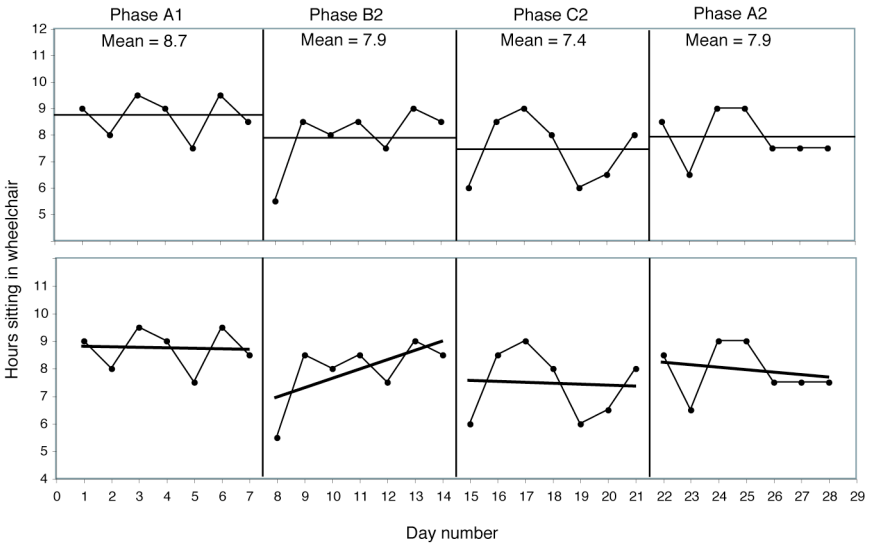


Figure 6-11: TIC means and trends for Participant 4.

Phase C2: Intervention, Condition 5 (TestChair2, FeatureSet2)

For Participant 4, daily sitting duration in TestChair2 with FeatureSet2 was 7.4 hours (SD = 1.2 hours). Visual analysis revealed increased variability of the data during this phase, but little difference in mean sitting duration from either of the earlier phases (A1 or B2). The trend of this data reversed back to a slightly negative slope – more similar to that found during the baseline phase (A1) than that for the Phase B2 data (see Figure 6-11).

Both the celeration line and two standard deviation band analyses comparing phases A1 and C2 data indicated a significantly lower sitting duration when this participant was using TestChair2 than when he used his own wheelchair (see Figure 6-12). However, the C Statistic (Z = 0.21) result indicated no significant difference in sitting duration between the two wheelchairs.

Celeration line comparison (see Figure 6-12) of the two interventions - phases B2 and C2 - indicated a significantly lower sitting duration when Participant 4 used TestChair2 with FeatureSet2 (Phase C2) than when he used TestChair2 with FeatureSet1 (Phase B2), however neither the two standard deviation band nor the C Statistic (Z = 0.21) analysis confirmed this difference in sitting duration across interventions.

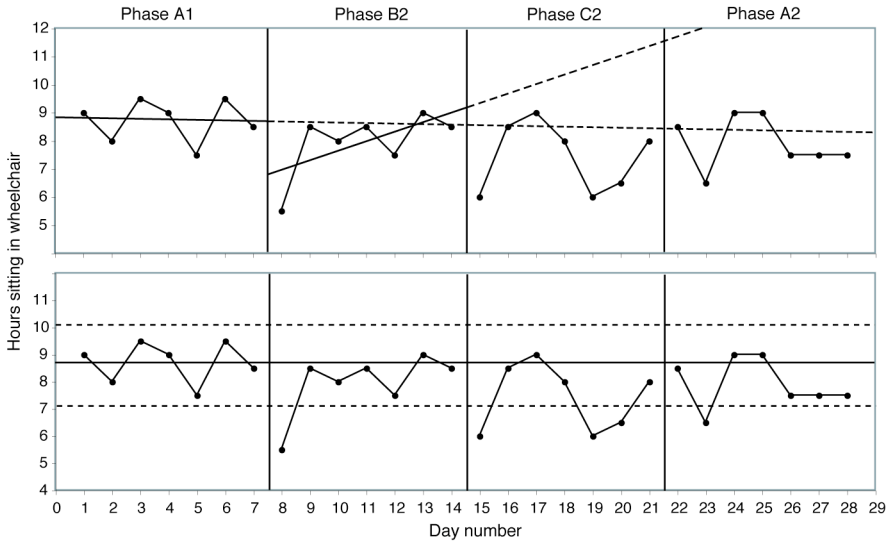


Figure 6-12: TIC celeration lines and two standard deviation bands for Participant 4.

Phase A2: Return to baseline, Condition 6

Mean sitting duration upon return to baseline was 7.9 (SD = 0.9). Visual analysis indicated little change in mean sitting duration or trend from the previous intervention phase (C2) to this return to baseline phase (see Figure 6-11). Analysis of this return to baseline data compared with that in the previous phase (C2) using the celeration line, two standard deviation band, and C Statistic (Z = 0.51) indicated no significant differences in sitting duration between TestChair2 with FeatureSet2 and this participant's own wheelchair.

Celeration line, two standard deviation band and C statistic analysis of data from the two baseline phases (A1 and A2) were also not significant (Z = 0.31) indicating no significant difference in sitting duration when using across the two baselines.

6.3.1.7 Participant 5

Phase A1: Baseline, Condition 1

During her baseline phase, Participant 5 used either a folding frame powered wheelchair with an alternating pressure air and foam seat cushion and sling upholstery for back support or a power seat lift chair (not a wheelchair) for all of her sitting. Her baseline sitting duration was 7.9 hours per day (SD = 1.4 hours). The trend of this data had a steep negative slope. Figure 6-13 presents the means and trends for all phases of TIC data for Participant 5. Participant 5 was randomized to an ACBA design.

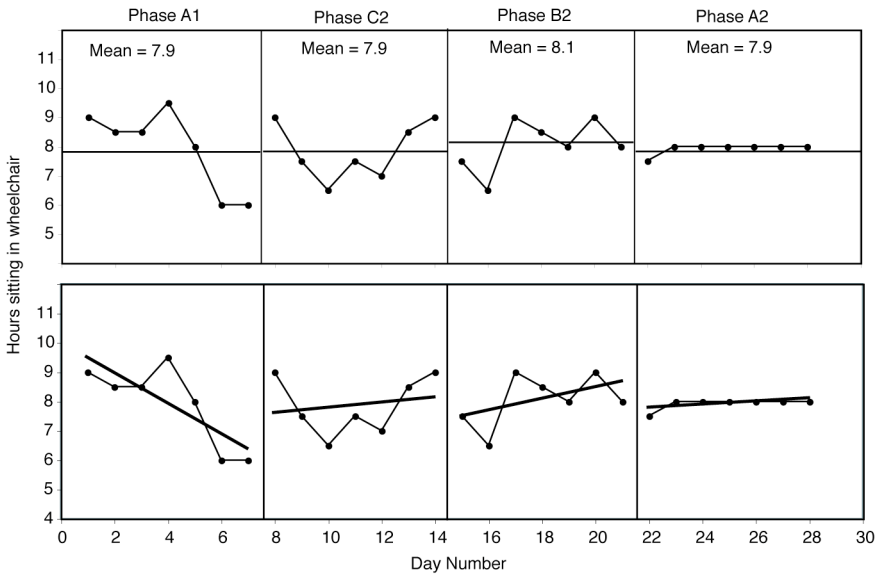


Figure 6-13: TIC means and trends for Participant 5

Phase C2: Intervention, Condition 5 (TestChair2, FeatureSet2)

Mean sitting duration in TestChair2 using FeatureSet2 was 7.9 hours per day (SD = 1.0 hours). Visual analysis revealed no difference in mean sitting duration between that in her chair and that in TestChair2 with FeatureSet2 (see Figure 6-13), however the trend of the data changed from a steep negative slope during Phase A1 to a slight positive slope during Phase C2, indicating increasing sitting durations when this participant was using TestChair2. Celeration line analysis indicated a significantly increased sitting duration when this participant was using TestChair2 with FeatureSet2 (see Figure 6-14) than when she was using her own wheelchair, however the two standard deviation band analysis failed to confirm this difference. The C statistic (Z = 2.15) analysis did confirm the significantly higher sitting duration when this participant was using TestChair2.

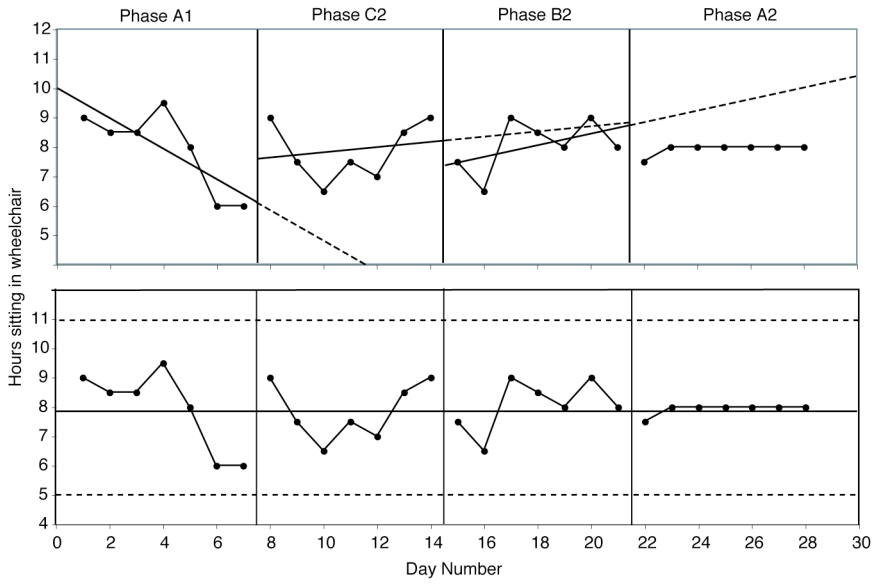


Figure 6-14: TIC celeration lines and two standard deviation bands for Participant 5

Phase B2: Intervention, Condition 4 (TestChair2, FeatureSet1)

Mean sitting duration in TestChair2 using FeatureSet1 was 8.1 hours per day (SD = 0.9 hours). Visual analysis revealed little difference in sitting duration mean levels from Phase A1 to Phase B2, however the trends for these two conditions were opposite from each other – with the trend for Phase A1 having a strong negative slope and the trend for Phase B2 having a slight positive slope (see Figure 6-13). Celeration line analysis of the Phase B2 data compared with the Phase A1 data indicated increased sitting duration in TestChair2 than that in her own wheelchair (see Figure 6-14). Neither the two standard deviation band nor the C Statistic (Z = 1.60) test indicated any significant difference in sitting duration from Phase A1 to Phase B2.

Analysis of Phase C2 and Phase B2 data, indicated no significant differences in sitting duration when using the two interventions (FeatureSet1 and FeatureSet2). Visual analysis indicated little difference between the mean sitting durations or trends of the data for these two interventions. The celeration line, two standard deviation band and C Statistic (Z = 0.46) analyses all indicated no significant difference in sitting duration when she used TestChair2 with FeatureSet1 or TestChair2 with FeatureSet2.

Phase A2: Return to baseline, Condition 6

Due to the delivery of this participant's new wheelchair, she used a different wheelchair for Phase A2 than she had used during Phase A1. Her new wheelchair was a powered wheelchair with powered seat tilt, powered back recline, and powered elevating legrests. The seat and back cushions were made of contoured foam on solid seat and back pans. Her mean sitting duration in this wheelchair was 7.9 hours per day (SD = 0.2 hours). Visual analysis of these data indicated a substantial decrease in the variability of her sitting duration, but very little difference in mean sitting duration between this phase and each of the other phases and a leveling out of the trend, while still maintaining a slight positive slope during this final phase (see Figure 6-13).

Celeration line analysis of Phase B2 and Phase A2 data indicated a significantly lower sitting duration when she returned to sitting in her own wheelchair, however neither the two standard deviation band analysis nor the C Statistic (Z = 0.10) indicated any significant difference in sitting duration between Phase B2 and Phase A2.

Comparison of the data from the two baseline phases was also performed. It is important to remember that the two wheelchairs used during these phases actually differed because of the delivery of a new wheelchair to this participant. Visual analysis of phase A1 and A2 data revealed no difference in mean sitting durations, but a large difference in trend of the data with a large negative slope for Phase A1 and very little positive slope for the Phase A2 data. Celeration line testing of the Phase A2 data using the trend from Phase A1 indicated significantly higher sitting duration when she was sitting in her new wheelchair (Phase A2). The two standard deviation band analysis of these two phases indicated no significant difference in sitting duration, but the C Statistic ($Z = 2.12$) result indicated significantly higher sitting duration for her new wheelchair used in the return to baseline phase (A2).

Table 6-5: TIC summary of results

Participant and type of comparison	Comparison	Celeration line	Two standard deviation band	C-Statistic		
		Sig.**	Sig.**	Z Score	*p*	*Sig.***
Participant 1: (ACBA design)						
Baseline → Intervention	A1 → C1	NS	NS	0.69	0.2451	NS
Baseline 1 → Baseline 2	A1 → A2	SIG higher	NS	0.43	0.3336	NS
Participant 1a: (ACBA design)						
Baseline → Intervention	A1 → C2	NS	NS	0.07	0.4721	NS
Baseline → Intervention	A1 → B2	SIG higher	NS	1.73	0.0418	SIG
Intervention → Intervention	C2 → B2	SIG lower	NS	0.15	0.4404	NS
Intervention → Baseline	B2 → A2	SIG lower	SIG lower	1.39	0.0823	NS
Baseline 1 → Baseline 2	A1 → A2	NS	NS	0.41	0.3409	NS
TestChair1 and TestChair2:						
Intervention 1 → Intervention 2	C1 → C2	SIG higher	NS	0.45	0.3264	NS
Intervention 1 → Intervention 2	C1 → B2	SIG higher	NS	0.15	0.4404	NS
Participant 2: (ABCA design)						
Baseline → Intervention	A1 → B1	Not enough data points	NS	0.17	0.4325	NS
Baseline → Intervention	A1 → B2	SIG lower	NS	0.98	0.1635	NS
Intervention → Intervention	B1 → B2	SIG lower	NS	0.58	0.2810	NS
Baseline → Intervention	A1 → C2	SIG lower	NS	0.67	0.2514	NS
Intervention → Intervention	B1 → C2	SIG lower	NS	0.17	0.4325	NS
Intervention → Intervention	B2 → C2	SIG higher	NS	0.99	0.1611	NS
Intervention → Baseline	C2 → A2	NS	NS	1.54	0.0618	NS
Baseline 1 → Baseline 2	A1 → A2	SIG lower	NS	0.96	0.1685	NS
Participant 3: (ACBA design)						
Baseline → Intervention	A1 → C2	SIG lower	NS	1.66*	0.0485	SIG
Baseline → Intervention	A1 → B2	SIG lower	NS	4.92*	< .001	SIG
Intervention → Intervention	C2 → B2	SIG higher	NS	1.39	0.0823	NS

Table 6-5 (continued)

Participant and type of comparison	Comparison	Celeration line	Two standard deviation band	C-Statistic		
		Sig.**	Sig.**	Z Score	*p*	*Sig.***
Intervention ⁄ Baseline	B2 ⁄ A2	SIG higher	NS	3.67*	0.0001	SIG
Baseline 1 ⁄ Baseline 2	A1 ⁄ A2	SIG lower	NS	0.80	0.2119	NS
Participant 4: (ABCA design)						
Baseline ⁄ Intervention	A1 ⁄ B2	SIG lower	NS	0.02*	0.4920	NS
Baseline ⁄ Intervention	A1 ⁄ C2	SIG lower	SIG lower	0.21*	0.4168	NS
Intervention ⁄ Intervention	B2 ⁄ C2	SIG lower	NS	0.37	0.3557	NS
Intervention ⁄ Baseline	C2 ⁄ A2	NS	NS	0.51	0.3050	NS
Baseline 1 ⁄ Baseline 2	A1 ⁄ A2	NS	NS	0.31	0.3783	NS
Participant 5: (ACBA design)						
Baseline ⁄ Intervention	A1 ⁄ C2	SIG higher	NS	2.15*	0.0158	SIG
Baseline ⁄ Intervention	A1 ⁄ B2	SIG higher	NS	1.60*	0.0548	NS
Intervention ⁄ Intervention	C2 ⁄ B2	NS	NS	0.46	0.3228	NS
Intervention ⁄ Baseline	B2 ⁄ A2	SIG lower	NS	0.10	0.4602	NS
Baseline 1 ⁄ Baseline 2	A1 ⁄ A2	SIG higher	NS	2.12*	0.0170	SIG

* Comparison series used for analysis

** Significance at the $p < 0.05$ level

6.3.2 GDA score baseline

The Bartlett test indicated serially dependent data for Participant 1a, Phase A2 (return to baseline) and for Participant 5, Phase A2. This serial dependency may interfere with accurate visual analysis (Bengali & Ottenbacher, 1998) and with the semi statistical procedures used for data analysis (Ottenbacher, 1986), therefore, the C-Statistic is relied on for indications of significant results for the GDA discomfort measure in these two participants. Table 6-6 indicates the results of the autocorrelation tests for the GDA scores. A summary of all of the GDA score results for all participants and across all analysis methods is presented at the conclusion of all of the GDA score results in Table 6-7.

Table 6-6: Autocorrelation test results for the GDA score discomfort measure

Participant/ test phase	Autocorrelation Coefficient (r)	Bartlett's Test	Autocorrelated?
Participant 1:			
A1	0.2752	0.4714	No
C1	0.0751	0.7559	No
A2	0.1015	0.5345	No
Participant 1a:			
A1	0.3829	0.4714	No
B2	0.1379	0.4851	No
C2	0.4100	0.6030	No
A2	0.6311	0.5164	Yes
Participant. 2			
A1	0.4181	0.4364	No
B1	0.2821	0.7559	No
B2	0.4466	0.6030	No
C2	0.0945	0.6030	No
A2	0.2612	0.4264	No
Participant 3:			
A1	0.2832	0.4364	No
B2	0.0574	0.4714	No
C2	0.1095	0.4472	No
A2	0.4080	0.4588	No
Participant 4:			
A1	0.1456	0.5774	No
B2	0.3383	0.5774	No
C2	0.1209	0.6030	No
A2	0.3372	0.5547	No
Participant 5			
A1	0.0646	0.4364	No
B2	0.1336	0.5345	No
C2	0.0141	0.4714	No
A2	0.7763	0.5345	Yes

6.3.2.1 Participant 1

Phase A1: Baseline, Condition 1

The mean GDA discomfort score for Participant 1 when using his own wheelchair was 57.1 (SD = 6.4). Visual analysis of these data showed a high degree of variability and a downward sloping trend line (see Figure 6-15). Participant 1 was randomized to an ACBA design.

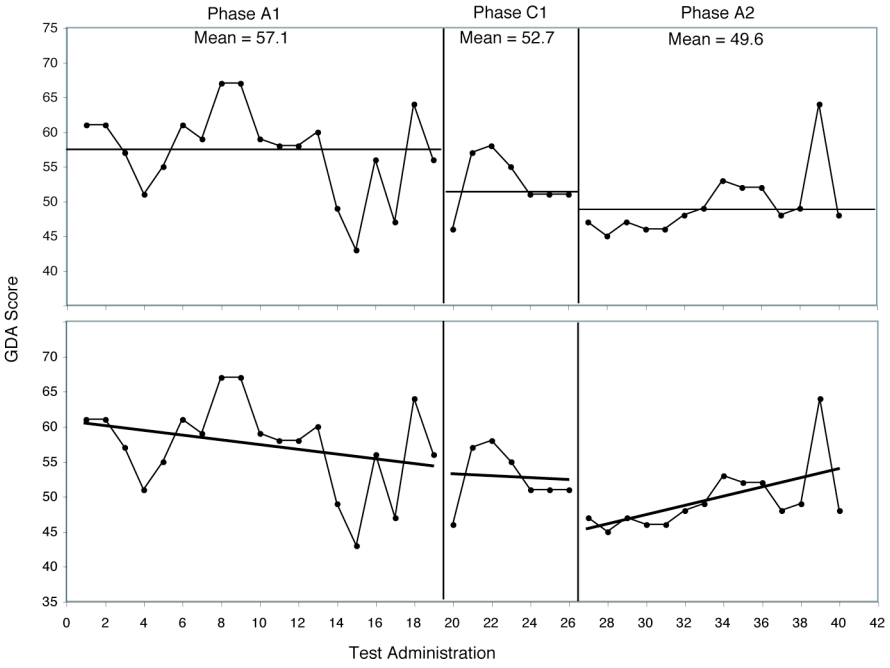


Figure 6-15: GDA score means and trends for Participant 1

Phase C1: Intervention, Condition 3 (TestChair1, FeatureSet2)

During Phase C1 testing, the mean GDA score for this participant was 52.7 (SD = 4.2). Visual analysis of these data compared with those in Phase A1 indicated decreased variability, a lower mean level, and a decrease in the slope of the trend line, but still maintaining a slightly negative slope (see Figure 6-15 for GDA means and phase trends). There were no significant differences in GDA score between Phase A1 and Phase C1 indicated by celeration line, two standard deviation band (see Figure 6-16), or C Statistic (Z = 1.62) analyses. This indicates no significant differences in discomfort levels between this participant's own wheelchair and TestChair1 with FeatureSet2.

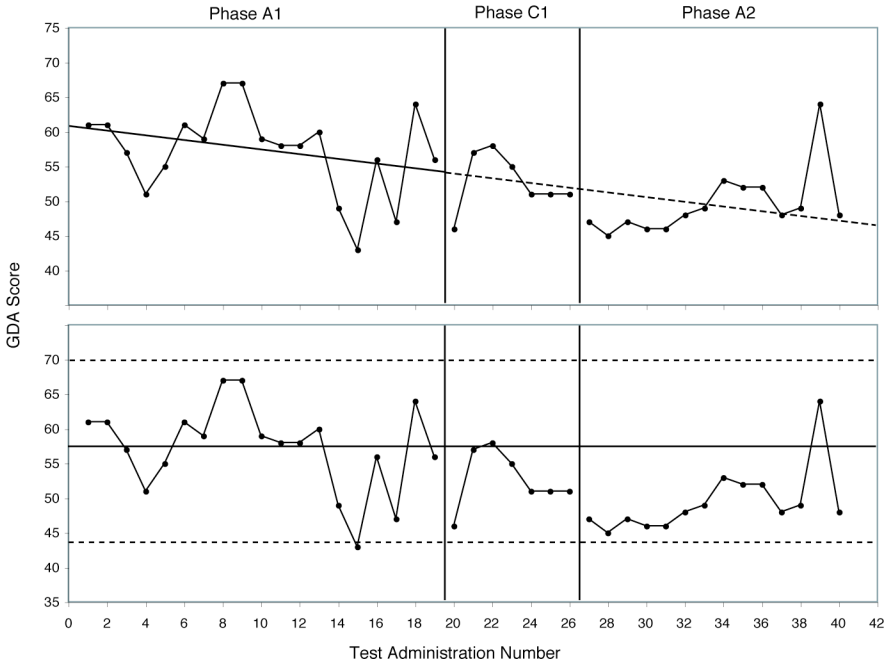


Figure 6-16: GDA celeration line and two standard deviation bands for Participant 1

Phase A2: Return to baseline, Condition 6

For the return to baseline phase, the mean GDA score was 49.6 (SD = 4.8). Visual analysis revealed a lower degree of variability of these data as compared with the original baseline (A1) data, particularly through the first several days of testing. The GDA mean was lower during this phase than during the original baseline (A1) and Phase C1, indicating a decline in discomfort as he progressed from phase to phase. The trend of this data did however have a reversed slope – with a moderate positive slope indicating increasing levels of discomfort during this final baseline phase. Celeration line and two standard deviation band analyses of the Phase C1 and Phase A2 data indicated no significant differences in discomfort level when he returned to using his own wheelchair. Analysis of the two baseline phases using the celeration line and two standard deviation band methods indicated no significant differences in discomfort from Phase A1 to Phase A2, but the C Statistic (Z = 2.59) comparison of phases A1 and A2 did indicate a significant difference in GDA score, which may have been due to the change in mean or the change in trend or a combination of the two (Tryon, 1982).

6.3.2.2 Participant 1a

Phase A1: Baseline, Condition 1

Due to the presence of serially dependent data for this participant (Phase A2, return to baseline), the C Statistic is relied on for determination of significant intervention effects. The GDA mean for this participant when using his own wheelchair was 50.2 (SD = 3.0). This participant was randomized to an ACBA design.

Phase C2: Intervention, Condition 5 (TestChair2, FeatureSet2)

The GDA score mean while seated in TestChair2 with FeatureSet2 was 50 (SD = 3.2). C Statistic (Z = 1.43) analysis of Phase A1 and Phase C2 data indicated no difference in discomfort level when this participant was seated in either his own wheelchair or TestChair2 with FeatureSet2.

Phase B2: Intervention, Condition 4 (TestChair2, FeatureSet1)

The GDA score mean for Phase B2 was 49.5 (SD = 2.2). The Z score from the C Statistic was 0.03, indicating no significant difference in discomfort between Phase A1 and Phase B2. The C Statistic (Z = 1.34) analysis of phases B2 and C2 data also indicated no significant difference in discomfort between the two different intervention phases (FeatureSet1 and FeatureSet2).

Phase A2: Return to baseline, Condition 6

The GDA mean for the return to baseline phase was 51.7 (SD = 1.9). When Phase B2 and Phase A2 data were analyzed using the C Statistic, there was no significant difference (Z = 0.30). Due to the serially dependent data, celeration line and two standard deviation band analyses were not performed for this participant, but these are presented in Figure 6-18 for illustration purposes.

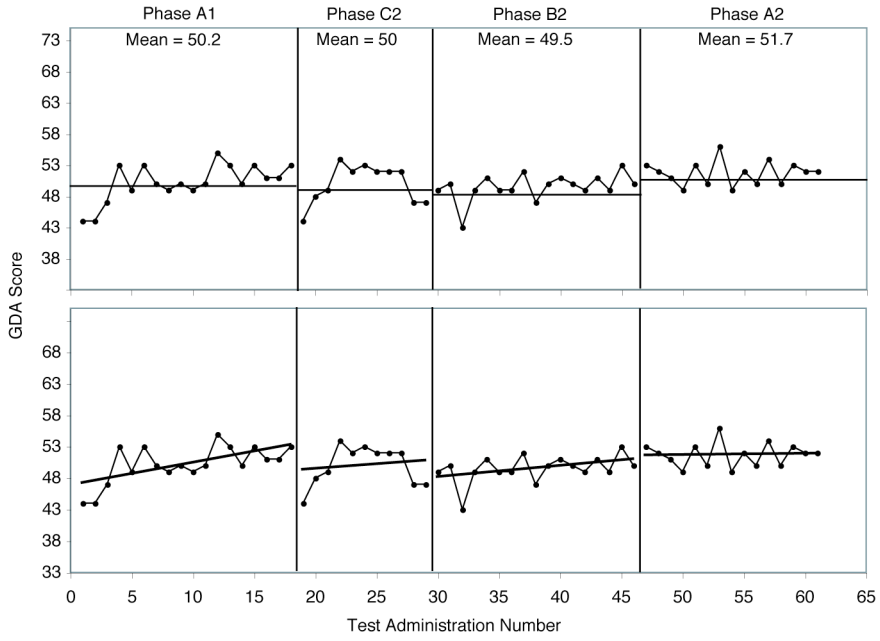


Figure 6-17: GDA score means and trends for Participant 1a

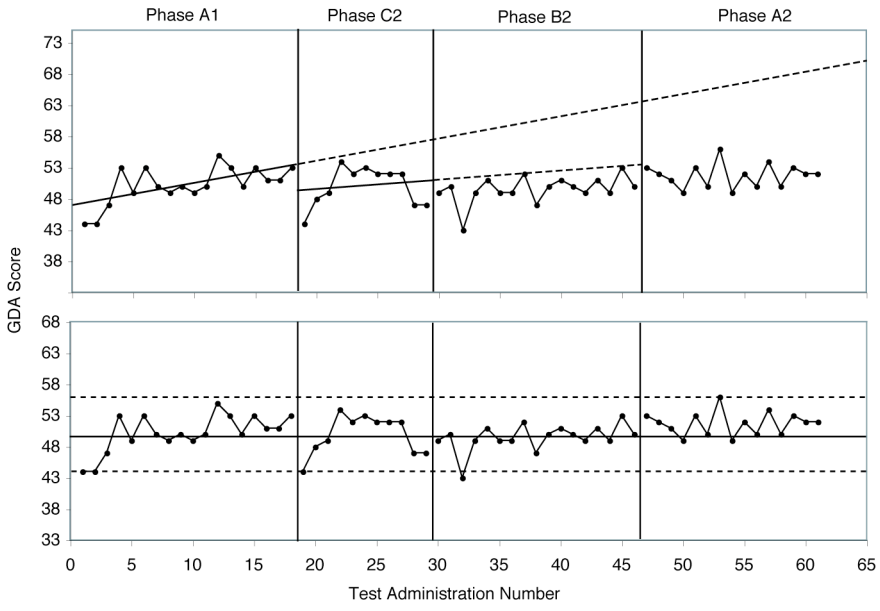


Figure 6-18: GDA score celeration line and two standard deviation bands for Participant 1a

(analysis not used due to serial dependency of Phase A2 data)

6.3.2.3 TestChair1 and TestChair2 comparison

For the first participant, additional analyses were performed based on his testing of both TestChair1 and TestChair2. For these analyses, results from Phase C1 (Participant 1, Condition 3) were compared with those from phases C2 and B2 (Participant 1a, conditions 4 and 5) to determine the presence of significant differences in discomfort level experienced between TestChair1 and TestChair2.

Visual analysis of these data graphed together indicated a slight difference in mean level from Phase C1 to phases C2 and B2 and differences in the slopes of the trend lines, with a slightly negative slope during Phase C1 and a slightly positive slope during phases C2 and B2 (see Figure 6-19). Celeration line comparisons of Phase C2 and B2 with Phase C1 indicated no significant change in discomfort level between TestChair1 with FeatureSet1 and TestChair2 with either FeatureSet1 or FeatureSet2. Two standard deviation band comparisons of Phase C1 with C2 and Phase C1 with B2 were also not significant (see Figure 6-20). The C Statistic ($Z = 1.94$) for Phase C1 and Phase C2 comparison was significant – indicating a significant difference in discomfort from TestChair 1 with FeatureSet2 to TestChair2 with FeatureSet2, but the Z score for the Phase C1 and Phase B2 comparison was not significant ($Z = 1.54$) indicating no differences in discomfort once both the test chair and the feature set in use were altered (TestChair1 with FeatureSet2 compared with TestChair2 with FeatureSet1). The comparison of Phase C2 and Phase B2 is discussed during the analysis of Participant 1a, as these phases were both completed during this trial and are not repeated here.

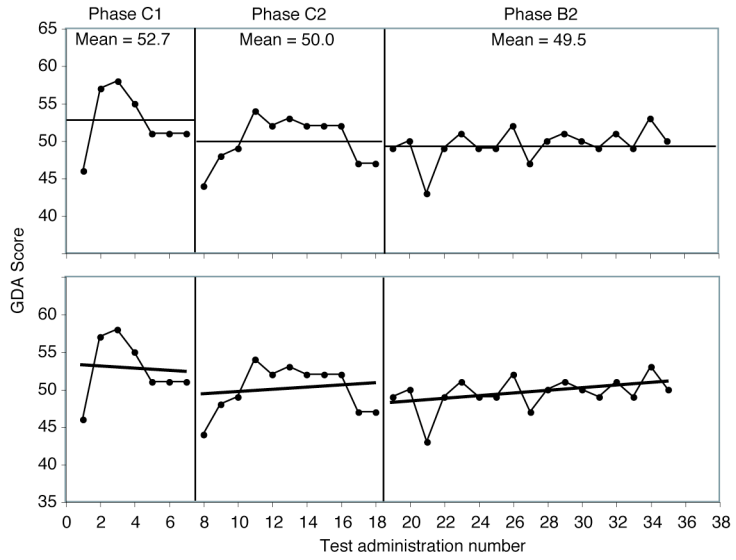


Figure 6-19: GDA means and trends for TestChair1 and TestChair2
(used for chair to chair comparison for the first research participant)

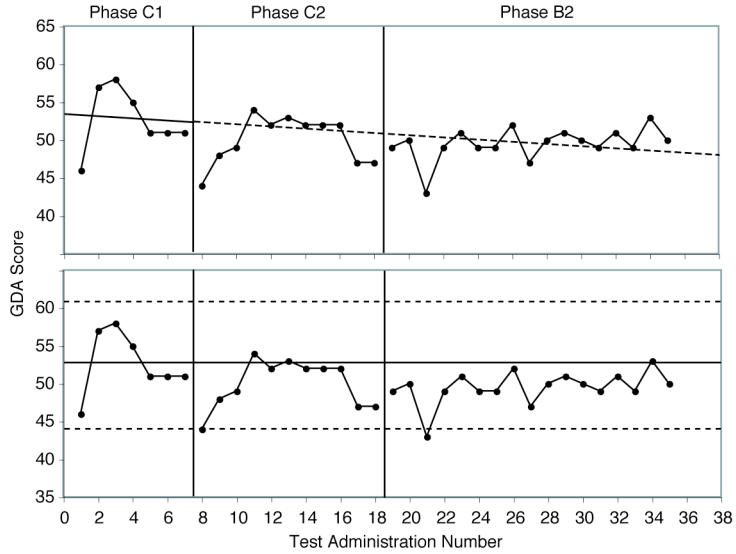


Figure 6-20: GDA score celeration line and two standard deviation bands for TestChair1 and TestChair2
(used for chair to chair comparison for the first research participant)

6.3.2.4 Participant 2

Phase A1: Baseline, Condition 1

For Participant 2, the baseline mean of the GDA discomfort score was 39.6 (SD = 9.3). Visual analysis of these data showed a high degree of variability and a repeating pattern – with two lower scores and one high score per day (at the end of the day). The trend of these data had neither a positive nor a negative slope (see Figure 6-21). This participant was randomized to an ABCA design. Due to problems discussed previously, his testing of TestChair1 was interrupted during Phase B1. He resumed his trial using TestChair2 with FeatureSet1 (Phase B2).

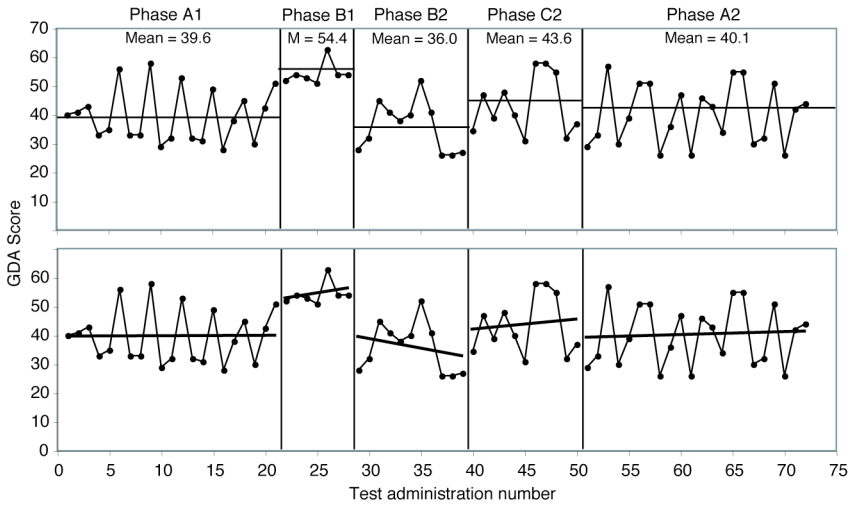


Figure 6-21: GDA score means and trends for Participant 2

Phase B1: Intervention, Condition 2 (TestChair1, FeatureSet1)

The Phase B1 GDA score mean was 54.4 (SD = 3.9). These data appeared to have less variability and a higher mean level upon visual inspection (see Figure 6-21). The trend of the GDA data with use of TestChair1 also became slightly positive – indicating an increasing discomfort level while using this wheelchair. The celeration line analysis of the Phase B1 and Phase A1 GDA scores indicated significantly higher discomfort when Participant 2 was using TestChair1 (see Figure 6-22), however the more rigorous two standard deviation band and C Statistic (Z = 1.52) analyses did not show a significant difference in this discomfort measure between this participant's own wheelchair and TestChair1 with FeatureSet1.

Phase B2: Intervention, Condition 4 (TestChair2, FeatureSet1)

When testing resumed following TestChair2 construction, this participant resumed his trial using TestChair2 with FeatureSet1 (Phase B2). The GDA mean score for this phase was 36.0 (SD = 8.8). Visual inspection of these data in comparison with the baseline data (Phase A1) indicated a slight change in GDA mean and a change in trend to a negative slope (from a neutral slope during Phase A1). Neither the celeration line nor the two standard deviation band analyses (see Figure 6-22) demonstrated any difference on this discomfort measure between the participant's own wheelchair (Phase A1) and TestChair2 with FeatureSet1 (Phase B2). The C Statistic test of Phase A1 and B2 data was also not significant (Z = 0.49).

Visual inspection of the data from phases B1 and B2 revealed differences in GDA discomfort score means and trends between these two phases. The GDA mean for Phase B1 was substantially higher than that for Phase B2 – indicating higher discomfort levels with TestChair1 use. The two trends also differ in slope – the Phase B1 trend had a positive slope and the Phase B2 trend a negative slope. This indicated increasing discomfort levels when this participant used

TestChair1 with FeatureSet1 and decreasing levels when he used TestChair2 with FeatureSet1. Celeration line analysis was problematic for this phase comparison. Even though all Phase B2 points fell below the celeration line generated from the Phase B1 trend line, the high proportion of points below the Phase B1 trend line necessitated a high number of observations below the celeration line to attain significance. Therefore, the results of celeration line analysis of Phase B1 to Phase B2 were not significant as this number was not attained during Phase B2 (11 points were collected and were all below the celeration line (see Figure 6-22), but 12 were necessary for a significant result). The two standard deviation band analysis did indicate a significantly lower discomfort level during Phase B2 when compared with Phase B1. Also, the C-Statistic ($Z = 2.93$) analysis confirmed this significant result.

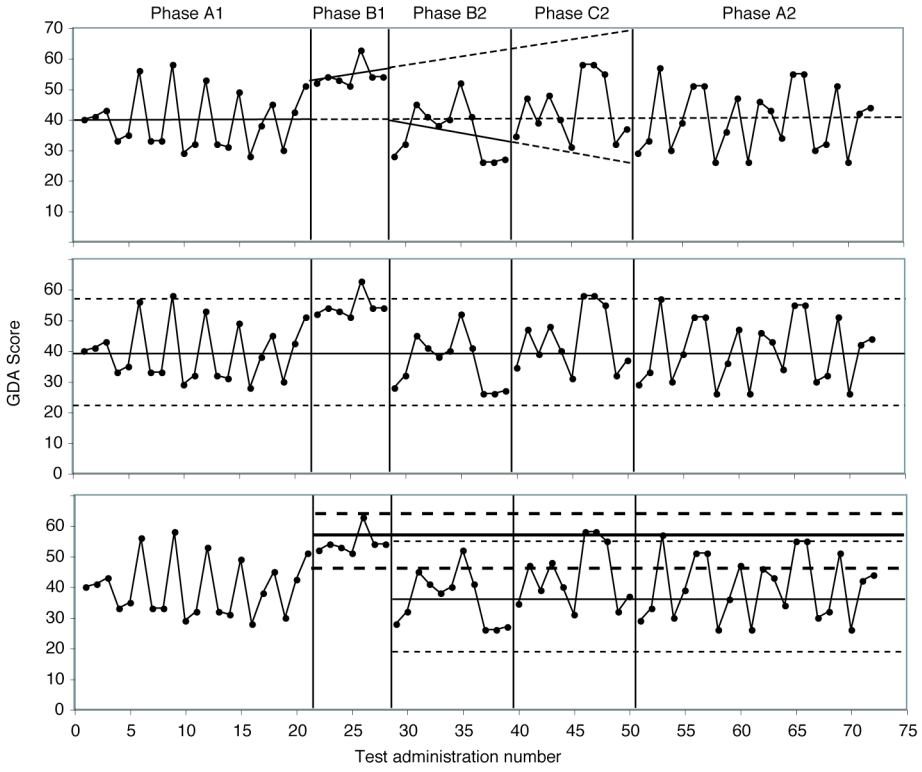


Figure 6-22: GDA celeration lines and two standard deviation bands for Participant 2
(Upper panel includes celeration lines for Phase A1 trend, Phase B1 trend and Phase B2 trend for comparisons of the intervention phases (B1, B2 and C2). Middle panel shows mean and two standard deviation bands for Phase A1, lower panel has mean and two standard deviation bands for Phase B1 (bold) and Phase B2)

Phase C2: Intervention, Condition 5 (TestChair2, FeatureSet2)

While seated in TestChair2 with FeatureSet2, Participant 2 had a GDA mean score of 43.6 (SD = 10.2). Visual inspection confirmed the increased variability of these data and indicated a difference in both mean and trend between the Phase C2 and Phase A1 data (see Figure 6-21). This participant had a higher mean for the GDA score data during Phase C2 – indicating increased levels of discomfort compared with those he experienced when using his own

wheelchair. The slope of the trend line during Phase C2 was also slightly positive and steeper than the slope of the trend line for the Phase A1 data, indicating an increasing level of discomfort based on the GDA measure. Celeration line analysis of data from phases A1 and C2 indicated no significant difference in discomfort between these two phases, however, the two standard deviation band did indicate a significantly higher discomfort score when this participant used TestChair2 with FeatureSet2 (Phase C2) than when he used his own wheelchair (see Figure 22). The C Statistic test of phase A1 and C2 data was in agreement with the celeration line result, indicating no difference in discomfort between GDA scores for these two phases ($Z = 0.72$).

Visual comparison of Phase B1 data and Phase C2 data indicated a lower mean GDA when this participant was using TestChair2 with FeatureSet2 (Phase C2) than when he was using TestChair1 with FeatureSet1 (Phase B1). The trends of these two data sets were quite similar, with the phase B1 trend having only a slightly steeper positive slope. Celeration line testing of Phase B1 and Phase C2 was not significant, due to the same problem with the number of data points collected (as described under phase B1 to B2 comparison results reported above). For the two standard deviation band analysis using Phase B1 as a baseline, Phase C2 GDA scores were significantly lower, indicating decreased levels of discomfort when using TestChair2 with FeatureSet2 (C2). C Statistic comparison of phases B1 and C2 was not significant ($Z = 1.24$), in agreement with the celeration line testing.

The final intervention-to-intervention analysis performed for the GDA measure of Participant 2 was the Phase B2 to Phase C2 comparison. Visual analysis again indicated a difference in both means and trends between these two intervention phases. The Phase C2 mean GDA was higher than that of Phase B2 and the trend indicated an increasing discomfort level, rather than a decreasing level associated with Phase B2. Both the celeration line and two

standard deviation band analyses indicated significantly higher discomfort levels during Phase C2 – use of TestChair2 with FeatureSet2, but the more rigorous C Statistic comparison of these phases was not significant (Z = 0.57) indicating no significant difference in discomfort levels across these two phases.

Phase A2: Return to baseline, Condition 6

The return to baseline phase resulted in a GDA mean score of 40.1 (SD = 10.4). Again, a high degree of data variability in this measure was noted on visual analysis, but little difference in GDA mean from compared with Phase C2 and a slight decrease in the slope of the trend line as compared with that in Phase C2. None of the analysis methods used (celeration line, two standard deviation band, or C Statistic) indicated any significant differences in GDA scores between the Phase C2 intervention phase and the return to baseline (A2) phase (Z = 0.54 for the C Statistic).

Visual comparison of the baseline (Phase A1) and return to baseline (Phase A2) indicated no differences in either means or trends for the data in these two phases. Celeration line, two standard deviation band and C Statistic (Z = 0.54) analyses all resulted in non significant results, indicating similarity of discomfort levels between the two baseline phases, as would be expected in the absence of carry over effects from the intervention phases.

6.3.2.5 Participant 3

Phase A1: Baseline, Condition 1

The GDA mean score for Participant 3 using his own wheelchair was 58.3 (SD = 9.8). Visual analysis revealed a high degree of variability and a positive sloping trend in these data (see Figure 6-23). This participant was randomized to an ACBA design.

Phase C2: Intervention, Condition 5 (TestChair2, FeatureSet2)

When using TestChair2 with FeatureSet2 (Phase C2), the GDA score mean for Participant 3 was 28.9 (SD = 4.1). Visual analysis of these data compared with those in Phase A1 indicated a large difference in GDA means between the two phases, indicating lower discomfort levels when this participant used TestChair2 (see Figure 6-23). Both the celeration line and the two standard deviation band analyses were significant (see Figure 6-24), as was the result of the C Statistic (Z = 5.50) comparison of Phase C2 and Phase A1.

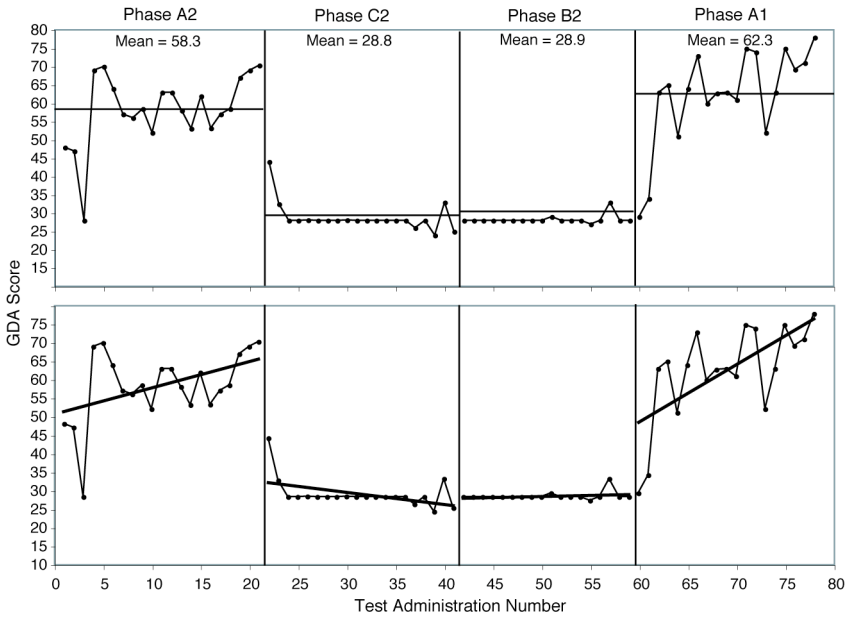


Figure 6-23: GDA score means and trends for Participant 3

Phase B2: Intervention, Condition 4 (TestChair2, FeatureSet1)

In TestChair1 with FeatureSet1 the GDA mean score for this participant was 28.8 (SD = 1.2). As with Phase C2, visual analysis of these data revealed a dramatic difference in GDA score means and trends from the baseline phase (A1). These mean and trend differences indicated lower discomfort levels when this participant was using TestChair2 than when he used his own wheelchair. As with the Phase C2 data, celeration line, two standard deviation band and C Statistic (Z = 5.02) analyses all indicated a significantly lower discomfort level when this participant used TestChair2 with FeatureSet1 (see Figure 6-24).

A comparison of Phase C2 and Phase B2 data was also performed to determine if there was a difference between discomfort levels associated with two feature sets. Visual inspection of this data (See Figure 6-23) indicated very similar means and trends for phases B2 and C2. Celeration line analysis of these two phases was significant, showing a higher GDA score or increased discomfort when using FeatureSet1 (Phase B2), however the two standard deviation band analysis of the these two phases did not indicate a significant difference in discomfort level. The C statistic analysis of Phase C2 and Phase B2 data was significant, in agreement with the celeration line result (Z = 2.69) and indicating a significant difference in discomfort levels with a higher discomfort when using FeatureSet1 compared with FeatureSet2.

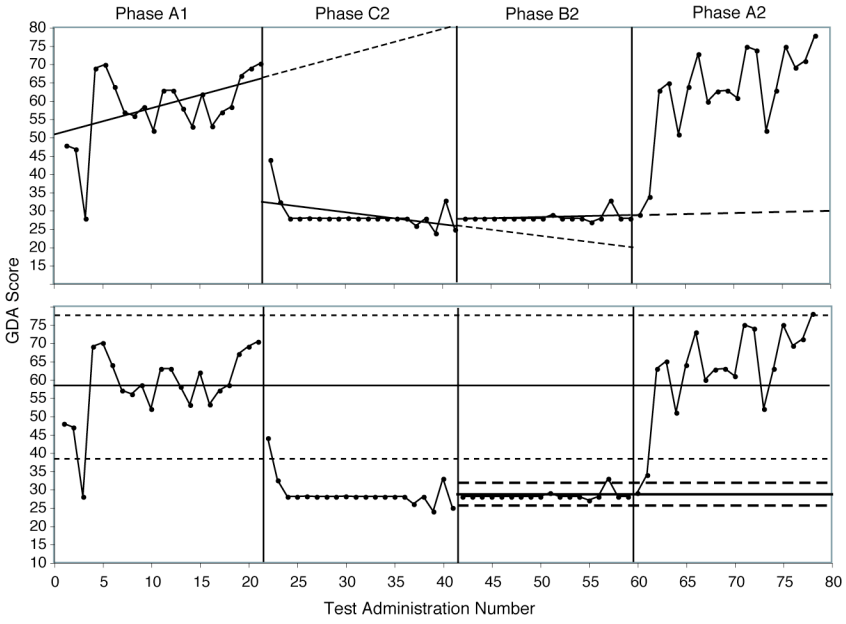


Figure 6-24: GDA celeration lines and two standard deviation bands for Participant 3 (lower panel shows mean and two standard deviation bands for Phase A1 data and Phase B2 data in bold)

Phase A2: Return to baseline, Condition 6

The GDA mean score for the return to baseline condition was 62.3 (SD = 13.1). Visual analysis of these data indicated a difference in GDA mean from Phase B2 to Phase A2 and a return to a mean similar to that of the original baseline – Phase A1. These data were much more variable than those of the intervention phases (B2 and C2) and the trend of the data had a steep positive slope – also different from the intervention phases and similar to the first baseline phase. Both celeration line and two standard deviation band analyses of Phase B2 and Phase A2 revealed significantly higher GDA scores upon return to baseline (A2). The C statistic also indicated a significant difference between the phase B2 and A2 data (Z = 5.67).

Visual inspection of the data from the two baselines indicated very similar means and trends, with a slight increase in the slope of the positive trend found in Phase A2. Celeration line, two standard deviation band and C Statistic (Z = 2.22) analyses all indicated a significantly lower discomfort level for the return to baseline phase than for the original baseline phase. This may have been due to a carry over effect from the transition between the final intervention phase (B2) back to a baseline phase. This participant's discomfort levels remained low for part of the Phase A2 data collection period because they had been so low during the intervention phases. The steepness of the trend line for the Phase A1 data also played a role in the celeration line significance for this final phase (see Figure 6-24).

6.3.2.6 Participant 4

Phase A1: Baseline, Condition 1

The baseline GDA score mean for this participant was 52.8 (SD = 10.5). Visual analysis of these scores indicated a high degree of variability and a trend with a positive slope – indicating an increasing level of discomfort through the baseline phase. Particularly high variability was noted during the first few days of testing, possibly due to this participant's unfamiliarity with the assessment tool itself. This participant was randomized to an ABCA design.

Phase B2: Intervention, Condition 4 (TestChair2, FeatureSet1)

Use of TestChair2 with FeatureSet1 (Phase B2) resulted in a mean GDA score of 56.0 (SD = 10.2). Variability of these data continued at approximately the same level as that found in the baseline phase (A1). Visual analysis revealed very little difference from the baseline phase in GDA mean and a slight decrease in the slope of the trend (see Figure 6-25). The celeration line analysis of the Phase B2 and Phase A1 data indicated a significantly lower GDA score, or lower level of seating discomfort, when he was seated in TestChair2 with FeatureSet1 than when he

was seated in his own wheelchair, however neither the two standard deviation band nor the C Statistic (Z = 0.87) analysis resulted in a finding of a significant difference in sitting discomfort between these two phases.

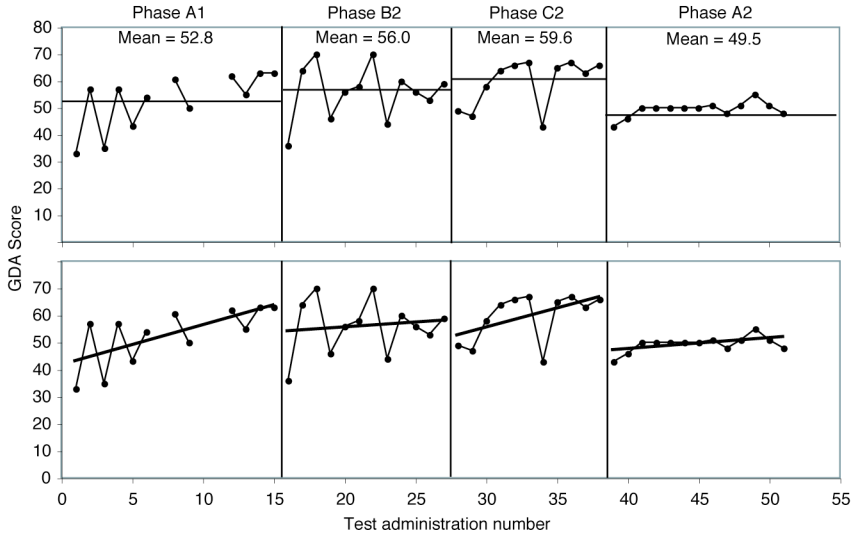


Figure 6-25: GDA score means and trends for Participant 4

Phase C2: Intervention, Condition 5 (TestChair2, FeatureSet2)

The GDA mean discomfort level for Participant 4 when using TestChair2 with FeatureSet2 was 59.6 (SD = 9.0). Visual analysis of these data indicated a slight increase in mean GDA scores during Phase C2 as compared with the baseline phase (A1). The slope of the trend line was not different from that of the Phase A1 data (see Figure 6-25). The celeration line comparison of Phase C2 and A1 data indicated a significantly lower discomfort level during this intervention. The two standard deviation band analysis was not significant for this phase (see Figure 6-26), nor was the result of the C-Statistic (Z = 0.91), indicating no significant difference in seating discomfort between TestChair1 with FeatureSet2 and his own wheelchair for these more rigorous analyses.

Visual comparison of the Phase C2 and Phase B2 data also indicated a slight increase in mean GDA scores. In addition, the trend lines for these two phases were also different – with the trend of the Phase C2 data having a steeper positive slope, indicating a more rapidly increasing level of seating discomfort when using TestChair2 with FeatureSet2 (see Figure 6-25). Celeration line, two standard deviation band (see Figure 6-26) and C Statistic (Z = 0.04) analyses of Phase B2 data compared with Phase C2 data all resulted in no significant differences in mean GDA scores between these two intervention phases, indicating no significant difference in discomfort levels between the two different feature sets (FeatureSet1 and FeatureSet2).

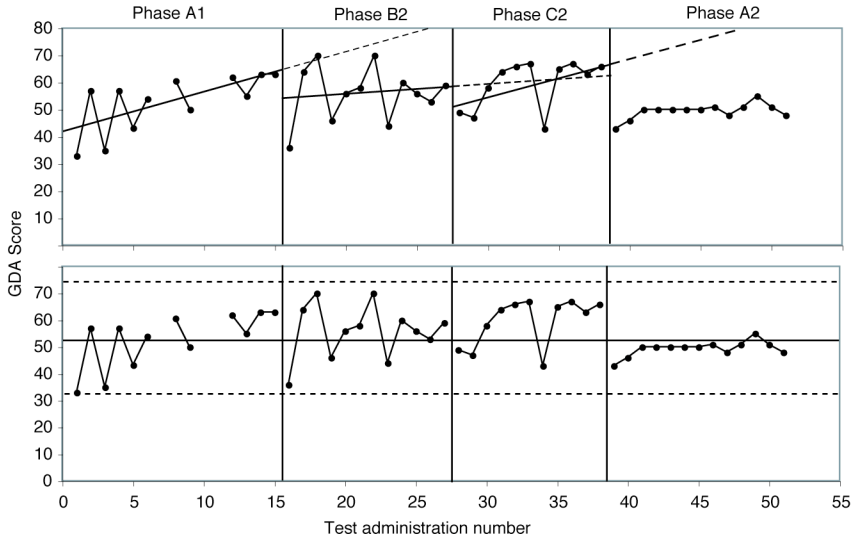


Figure 6-26: GDA score celeration lines and two standard deviation bands for Participant 4

Phase A2: Return to baseline, Condition 6

Upon return to baseline, the GDA mean was 49.5 (SD = 2.9). Visually, these data appeared much more stable in nature. The mean level of these data appeared lower than those of all previous phases and the trend in these data was much more level (see Figure 6-25). Celeration line analysis of data from phases A2 and C2 indicated a significantly lower discomfort level upon return to baseline. Two standard deviation band analysis of this same data did not result in a significant finding. However, the C Statistic analyses of Phase A2 and Phase C2 data was significant (Z = 1.94), confirming the significantly lower discomfort level found with the celeration line analysis and the change in trend of the Phase A2 data compared with that of the Phase C2 data.

Comparison of the data from both baselines (A1 and A2) indicated a lower mean level upon return to baseline, but not substantially. The trend from the Phase A2 data was much more level than that in Phase A1 which had a positive sloping trend. Celeration line comparison of Phase A1 and Phase A2 data was significant indicating a lower level of discomfort during the return to baseline phase than that of the first baseline (Phase A1). Neither the two standard deviation band nor the C Statistic (Z = 0.02) analysis resulted in a significant finding.

6.3.2.7 Participant 5

Phase A1: Baseline, Condition 1

For Participant 5, the baseline GDA mean score was 60.9 (SD = 4.1). Participant 5 was randomized to an ACBA design. Graphic representation of these data is presented in Figure 6-27, but was not used during analysis, due to the serial dependency of the Phase A2 data, discovered using Bartlett's test. Due to this serial dependency, the C Statistic was relied on for all phase comparisons for this participant.

Phase C2: Intervention, Condition 5 (TestChair2, FeatureSet2)

The mean GDA score when this participant sat in TestChair2 with FeatureSet2 was 50.1 (SD = 8.5). The C Statistic result was significant (Z = 1.92) indicating a significantly lower discomfort level between her own wheelchair and TestChair2 with FeatureSet2.

Phase B2: Intervention, Condition 4 (TestChair2, FeatureSet1)

When Participant 5 was seated in TestChair2 with FeatureSet1, his GDA discomfort score mean was 57.7 (SD = 2.7). The C-Statistic test of the Phase B2 and A1 data was not significant (Z = 0.59), indicating no difference in discomfort level between her own wheelchair and TestChair2 with FeatureSet1. When an analysis of the difference between GDA scores for phases B2 and C2, the result was significant (Z = 2.05) at the 0.05 level, indicating a significant difference

between FeatureSet1 and FeatureSet2 on TestChair2. This test indicated a higher mean level for FeatureSet1 and a change in trend for this data when compared with the GDA data when she was using TestChair2 with FeatureSet2.

Phase A2: Return to baseline, Condition 6

The GDA mean for the return to baseline phase was 60.5 (SD = 3.5). These data were found to be serially dependent using Bartlett's test. The C Statistic analysis of Phase A2 and Phase B2 data was not significant (Z = 0.94), indicating no significant difference in discomfort between TestChair2 with FeatureSet1 and her own wheelchair (used during the return to baseline phase). The C Statistic (Z = 1.05) analysis of data from phases A1 and A2 was also not significant, indicating no difference in discomfort between the two chairs she used for her baseline phases (A1 and A2).

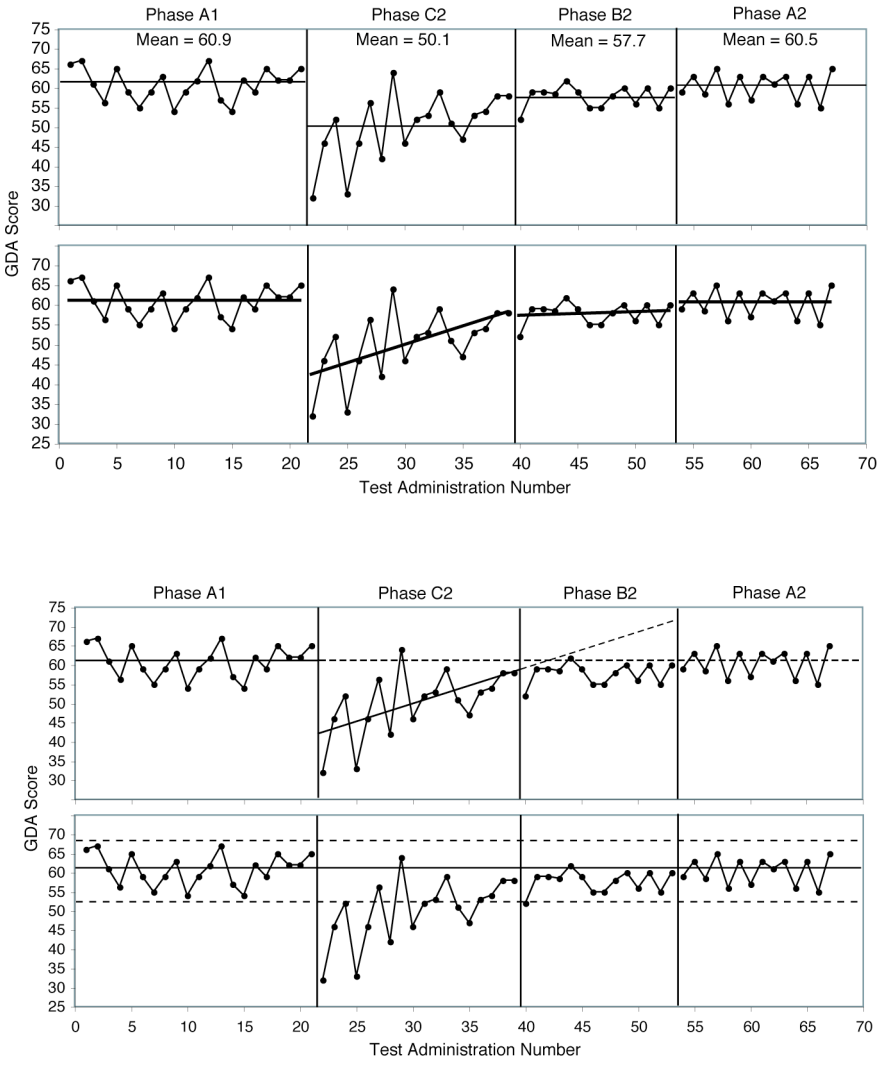


Figure 6-27: Graphed GDA score data for Participant 5

(mean levels and trends (top half of figure) and celeration lines and two standard deviation bands (lower half of figure). These were not used during analysis due to serial dependency of Phase A2 data)

Table 6-7: GDA score summary of results

Participant and type of comparison	Comparison	Celeration line	Two standard deviation band	C-Statistic		
		*SIG***	*SIG***	Z Score	*p*	*SIG***
Participant 1: (ACBA design)						
Baseline → Intervention	A1 → C1	NS	NS	1.62	0.0526	NS
Baseline 1 → Baseline 2	A1 → A2	NS	NS	2.59	0.0048	SIG
Participant 1a: (ACBA design)						
Baseline → Intervention	A1 → C2	†	†	1.43*	0.0764	NS
Baseline → Intervention	A1 → B2	†	†	0.03*	0.4880	NS
Intervention → Intervention	C2 → B2	†	†	1.34*	0.0901	NS
Intervention → Baseline	B2 → A2	†	†	0.30	0.3821	NS
Baseline 1 → Baseline 2	A1 → A2	†	†	1.80	0.0359	SIG
TestChair1 and TestChair2:						
Intervention 1 → Intervention 2	C1 → C2	NS	NS	1.94	0.0262	SIG
Intervention 1 → Intervention 2	C1 → B2	NS	NS	1.54	0.0618	NS
Participant 2: (ABCA design)						
Baseline → Intervention	A1 → B1	SIG higher	NS	1.52*	0.0643	NS
Baseline → Intervention	A1 → B2	NS	NS	0.49*	0.3121	NS
Intervention → Intervention	B1 → B2	Not enough data points	SIG lower	2.93	0.0017	SIG
Baseline → Intervention	A1 → C2	NS	SIG higher	0.72*	0.2358	NS
Intervention → Intervention	B1 → C2	Not enough data points	SIG lower	1.24	0.1075	NS
Intervention → Intervention	B2 → C2	SIG higher	SIG higher	0.57*	0.2843	NS
Intervention → Baseline	C2 → A2	NS	NS	0.54	0.2946	NS
Baseline 1 → Baseline 2	A1 → A2	NS	NS	1.29*	0.0985	NS
Participant 3:						
Baseline → Intervention	A1 → C2	SIG lower	SIG lower	5.50	< .001	SIG
Baseline → Intervention	A1 → B2	SIG lower	SIG lower	5.02	< .001	SIG
Intervention → Intervention	C2 → B2	SIG higher	NS	2.69*	0.0036	SIG

Table 6-7 (continued)

Participant and type of comparison	Comparison	Celeration line	Two standard deviation band	C-Statistic		
		*SIG***	*SIG***	Z Score	*p*	*SIG***
Intervention → Baseline	B2 → A2	SIG higher	SIG higher	5.67	< .001	SIG
Baseline 1 → Baseline 2	A1 → A2	SIG lower	SIG lower	2.22	0.0132	SIG
Participant 4:						
Baseline → Intervention	A1 → B2	SIG lower	NS	0.87	0.1921	NS
Baseline → Intervention	A1 → C2	SIG lower	NS	0.91	0.1814	NS
Intervention → Intervention	B2 → C2	NS	NS	0.04	0.4840	NS
Intervention → Baseline	C2 → A2	SIG lower	NS	1.94	0.0262	SIG
Baseline 1 → Baseline 2	A1 → A2	SIG lower	NS	0.02	0.4920	NS
Participant 5:						
Baseline → Intervention	A1 → C2	†	†	1.92	0.0274	SIG
Baseline → Intervention	A1 → B2	†	†	0.59	0.2776	NS
Intervention → Intervention	C2 → B2	†	†	2.05	0.0202	SIG
Intervention → Baseline	B2 → A2	†	†	0.94	0.1736	NS
Baseline 1 → Baseline 2	A1 → A2	†	†	1.05	0.1469	NS

* Comparison series used for analysis

** Significance at the $p < 0.05$ level

† Excluded these analyses secondary to serially dependent data (relied solely on C Statistic for analysis of significance)

6.3.3 DIS score baseline

The Bartlett test indicated serially dependent data for Participant 1, Phase A1, and for Participant 5, Phase A2 (see Table 6-8). As noted previously, this serial dependency may interfere with accurate visual analysis (Bengali & Ottenbacher, 1998) and with the semi statistical procedures used (Ottenbacher, 1986), so the C-statistic is relied on for judging significance of the results for these two participants under all conditions. A summary of all of the DIS results for all participants and all analysis methods is presented in Table 6-9, found at the conclusion of this section of results.

Table 6-8: Autocorrelation test results for the DIS score measure

Participant/ test phase	Autocorrelation Coefficient (r)	Bartlett's Test	Autocorrelated?
Participant 1:			
A1	0.6662	0.4714	Yes
C1	0.3415	0.7559	No
A2	0.0924	0.5345	No
Participant 1a:			
A1	0.0231	0.4714	No
B2	0.2798	0.4851	No
C2	0.3131	0.6030	No
A2	0.3259	0.5164	No
Participant. 2			
A1	0.0775	0.4364	No
B1	0.1321	0.7559	No
B2	0.5105	0.6030	No
C2	0.1887	0.6030	No
A2	0.2296	0.4264	No
Participant 3:			
A1	0.2037	0.4364	No
B2	0.4245	0.4714	No
C2	0.2860	0.4472	No
A2	0.1760	0.4472	No
Participant 4:			
A1	0.1252	0.5345	No
B2	0.5407	0.5774	No
C2	0.2609	0.6030	No
A2	0.0298	0.5547	No
Participant 5			
A1	0.2143	0.4364	No
B2	0.3161	0.5547	No
C2	0.0028	0.4714	No
A2	0.5815	0.5345	Yes

6.3.3.1 Participant 1

Phase A1: Baseline, Condition 1

The DIS mean score for this baseline phase was 33.8 (SD = 5.1). Due to the serial dependency found in these data, the C-Statistic is relied on for a determination of significant treatment effects under the intervention phase (Phase C1). This participant was randomized to an ACBA design.

Phase C1: Intervention, Condition 3 (TestChair1, FeatureSet2)

The mean DIS score for this phase was 27.4 (SD = 2.8). The C-statistic comparison of Phase A1 and Phase C2 was not significant (Z = 0.54), indicating no difference in discomfort as measured by the DIS scale between this participant's own wheelchair and TestChair1 with FeatureSet2. As noted, visual analysis, celeration line and two standard deviation band analyses were not performed due to the serial dependency of these baseline data. This trial was interrupted following five days of testing due to the development of redness under this participant's ischial tuberosity – a pre-established stopping point due to safety considerations. TestChair1 use was discontinued and this participant moved directly into Phase A2 – return to baseline testing.

Phase A2: Return to baseline, Condition 6

For the return to baseline phase, the mean DIS score was 24.9 (SD = 1.92). C-Statistic analysis comparing phase A1 and A2 data was significant (Z = 2.06), indicating a significant difference in discomfort level or in the trends of these data from the first baseline condition to the second.

6.3.3.2 Participant 1a

Phase A1: Baseline, Condition 1

The mean DIS score for Participant 1a when he was using his own wheelchair during this phase was 21.4 (SD = 1.6). Visual analysis of these data indicated a nearly level trend with only a slightly negative slope, indicating a declining discomfort level during this phase of testing. This participant was randomized to an ACBA design.

Phase C2: Intervention, Condition 5 (TestChair2, FeatureSet2)

The mean DIS score while using TestChair2 with FeatureSet2 was 21.3 (SD = 2.1). Visually, the DIS means remained unchanged between Phase A1 and C2, but the trends of the Phase C2 data had a much steeper negative slope – indicating declining discomfort levels through the Phase C2 period (see Figure 6-28). None of the semi-statistical (celeration line or two standard deviation band – see Figure 6-29) or statistical (C Statistic, Z = 1.18) procedures used to compare the A1 to C2 data indicated a significant difference in these data – indicating no difference in discomfort levels between this participant's own wheelchair and TestChair1 with FeatureSet2.

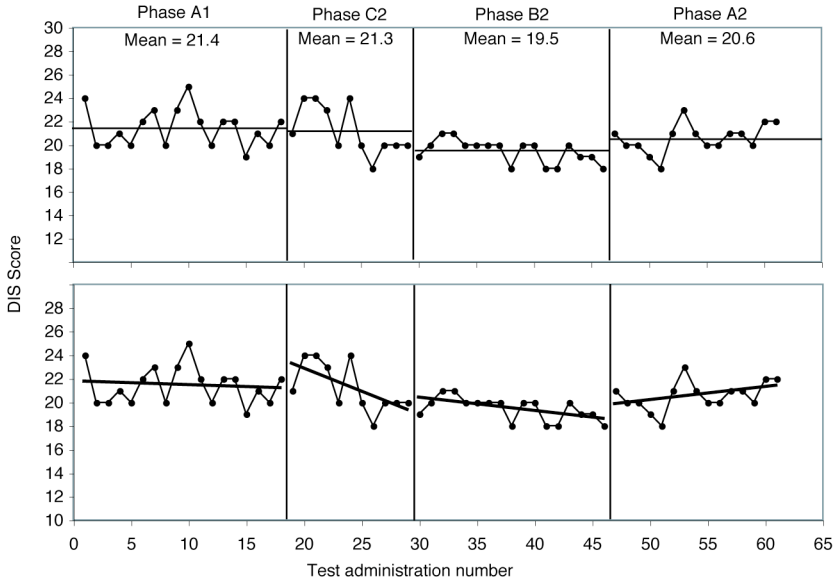


Figure 6-28: DIS score means and trends for Participant 1a

Phase B2: Intervention, Condition 4 (TestChair2, FeatureSet1)

The DIS mean score for this participant while using TestChair2 with FeatureSet1 was 19.5 (SD = 1.0). Visual analysis of these data indicated a lower DIS mean during the intervention phase (B2) than that of the baseline phase (A1) and a trend line with a more negative slope than the trend of the baseline data, indicating a decreasing amount of discomfort throughout the intervention phase that was not present during the baseline. The celeration line comparison of the Phase A1 and Phase B2 data was significant – with significantly lower discomfort scores found when this participant was using TestChair2 with FeatureSet1 than those when he was using his own wheelchair (see Figure 6-29). Moreover, the two standard deviation band comparison and the C Statistic test were also significant (Z = 2.55) indicating a significantly lower discomfort level during Phase B2 than during Phase A1 (baseline).

Visual analysis of the Phase B2 data compared with the Phase C2 data indicated a lower DIS mean during the second intervention phase (B2) and a shallower sloping trend during Phase B2 than during Phase C2 – still indicative of a declining discomfort level, but not as rapidly declining as that when using TestChair2 with FeatureSet2. Neither the celeration line nor the two standard deviation band comparison of Phase B2 and C2 data indicated a significant difference in discomfort level between these two interventions (FeataureSet1 and FeatureSet2), but the C-Statistic comparison was significant (Z = 2.78) indicating not only the difference in discomfort level, but also in the trends of the data in these two phases. This indicated that the effects from the FeatureSet1 were different from those of FeatureSet2 for this participant.

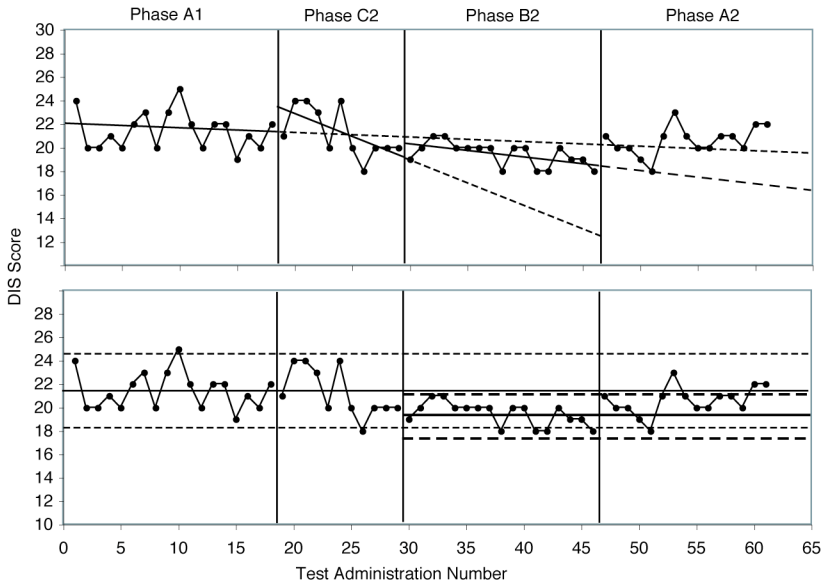


Figure 6-29: DIS score celeration lines and two standard deviation bands for Participant 1a (Upper panel shows celeration lines from phase A1, C2 and B2 trend lines, lower panel shows mean and two standard deviation bands for Phase A1 data and Phase B2 data - in bold)

Phase A2: Return to baseline, Condition 6

For the return to baseline phase, the mean DIS score was 20.6 (SD = 1.2). Visual analysis of these data in comparison with those of the preceding intervention (Phase B2) indicated a return to a higher mean discomfort score and a reversal of trend to one with a positive slope rather than a negative slope – indicating an increasing discomfort level when this participant returned to using his own wheelchair. All of the semi statistical and statistical (C Statistic - Z = 2.37) comparisons of the data from phases B2 and A2 were significant (See Figure 6-29 for celeration line and two standard deviation band depictions), indicating higher levels of discomfort when this individual returned to using his own wheelchair compared with those experienced during use of TestChair2 with FeatureSet1.

Visual comparison of the data from the two baseline phases – A1 and A2 indicated no substantial difference in means, but a difference in trend from a fairly neutral slope during the first baseline (A1) to a trend with a positive slope during the second baseline phase (A2). Neither the celeration line nor the two standard deviation band analyses comparing the two baseline phases was significant, indicating no significant differences in DIS levels between the two baseline phases. The C-Statistic comparing these data sets (phases A1 and A2) was also not significant (Z = 1.47), indicating no significant difference in discomfort level or trends between the two baseline phases.

6.3.3.3 TestChair1 and TestChair2 comparison

For this first participant, additional analyses were performed based on his testing of both test wheelchairs. These included comparisons of Phase C1 with Phase C2 and Phase C1 with Phase B2 to determine the presence of significant differences between TestChair1 and TestChair2.

Visual comparison of Phase C1 (Participant 1, Condition 3) with Phase C2 (Participant 1a, Condition 5) revealed a difference in mean levels, with Phase C2 data exhibiting a lower mean DIS level (see Figure 6-30) or lower participant discomfort. The trends of these data also differed with both phases exhibiting downward sloping trends, but that in Phase C2 had an increased amount of slope – indicating a more rapidly declining discomfort level during testing of TestChair2 with FeatureSet2. Both the celeration line and the two standard deviation band analyses indicated a significantly lower DIS score for TestChair2 over TestChair1 (see Figure 6-31). The C statistic (Z = 2.58) was also significant for the Phase C1 and Phase C2 comparison, again indicating the lower discomfort level and the change in trend when using TestChair2.

Comparison of Phase C1 and Phase B2 data also revealed a different mean level on visual inspection, with a lower discomfort level when this participant was seated in TestChair2 with FeatureSet1 than that he experienced when using TestChair1 with FeatureSet2. The trends of the data for these two phases were very similar – both containing a slight downward slope indicative of a declining discomfort level within each phase. All other analyses also indicated a lower discomfort level when this participant used TestChair2 with FeatureSet1(C Statistic Z = 3.72) than when he used TestChair1 with FeatureSet2.

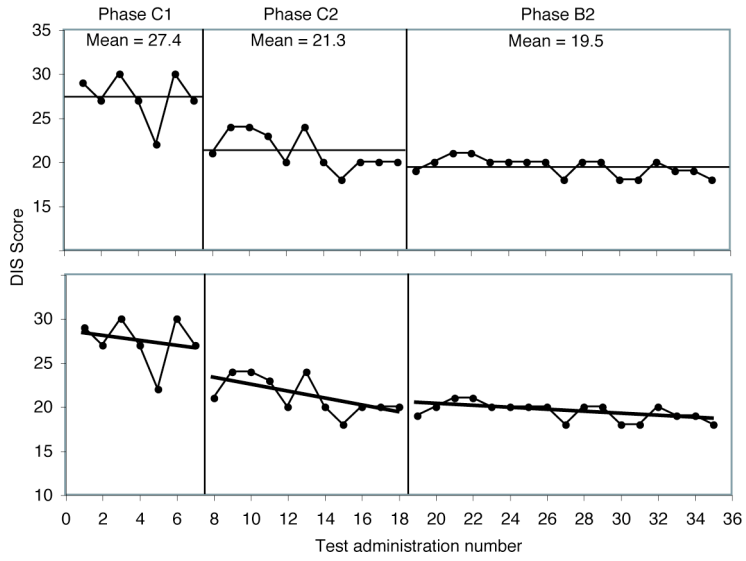


Figure 6-30: DIS score means and trends for TestChair1 and TestChair2 (first participant)

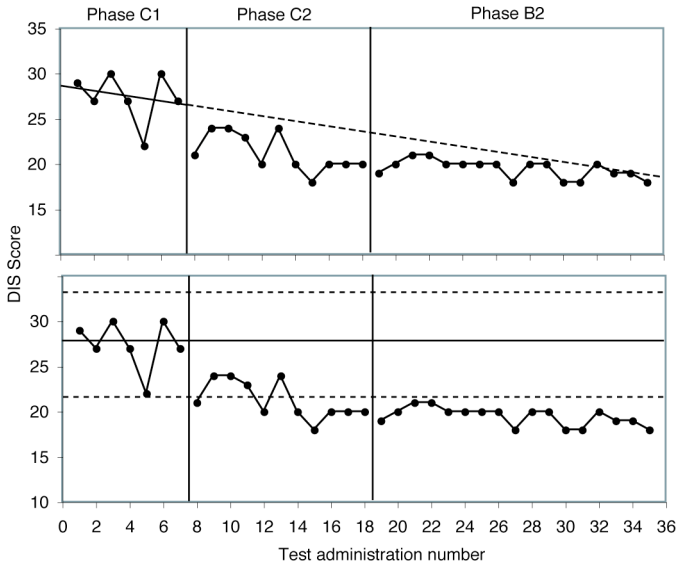


Figure 6-31: DIS score celeration lines and two standard deviation bands (graphs for TestChair1 and TestChair2 comparison - first participant)

6.3.3.4 Participant 2

Phase A1: Baseline, Condition 1

The baseline mean DIS score for Participant 2 was 12.7 (SD = 1.0). These baseline data exhibited a trend with a positive slope, indicating increasing discomfort levels through his baseline phase. This participant was randomized to an ABCA design and, due to discomfort and function related problems he experienced with TestChair1, completed an interrupted trial of TestChair1 (FeatureSet1 only) and a full trial of TestChair2.

Phase B1: Intervention, Condition 2 (TestChair1, FeatureSet1)

For Phase B1 testing (TestChair1 with FeatureSet1), the DIS mean score for this participant was 14.8 (SD = 1.3). Visual analysis of these data indicated a slight increase in mean and a decline in the amount of positive slope in the trend from Phase A1 to Phase B1 (see Figure 6-32). The other very noticeable trait is the small number of observations in Phase B1 compared with Phase A1. Both the celeration line and the two standard deviation band analyses indicated a significantly higher discomfort level when this participant was using TestChair1 with FeatureSet2 than he experienced when using his own wheelchair (see Figure 6-33). The result of the C Statistic comparison of these two phases confirmed this difference in discomfort level (Z = 2.53). These results were also in agreement with his anecdotal reports of discomfort – which were the main reason for removing and redesigning the test wheelchair.

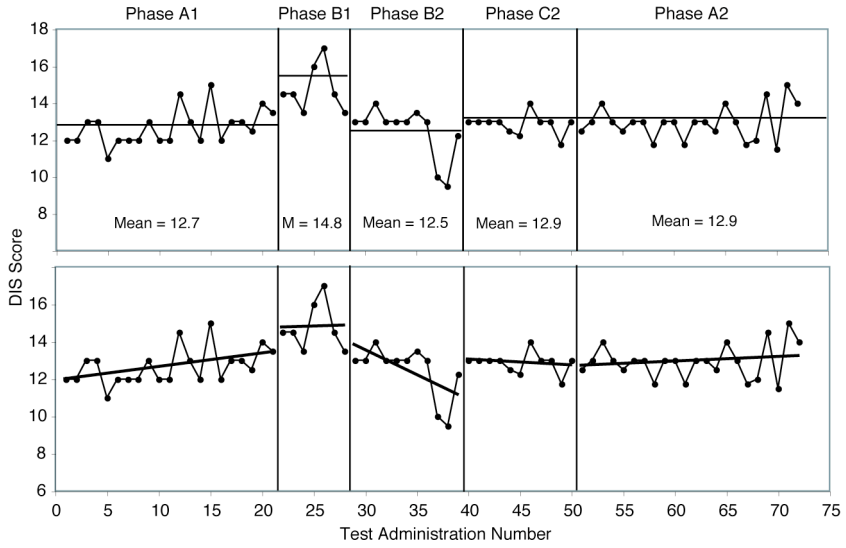


Figure 6-32: DIS score means and trends for Participant 2

Phase B2: Intervention, Condition 4 (TestChair2, FeatureSet1)

The mean DIS score for Participant 2 using TestChair2 with FeatureSet1 was 12.5 (SD = 1.4). Visual analysis of these data revealed very little difference in DIS means, but a reversal of trends for these two phases of data. The Phase A1 trend had a slight positive slope – indicating increasing discomfort levels when he was using his own wheelchair, but the trend for the Phase B2 data had a steep downward slope – indicating decreasing discomfort levels during the time he used TestChair2 with FeatureSet1. Both the celeration line and the two standard deviation band comparisons of these phases indicated significantly lower discomfort levels (see Figure 6-33) when he was using TestChair2 with FeatureSet1, however, the more rigorous C Statistic result did not reach a level of significance (Z = 1.45), failing to confirm the results of the other analyses and indicating no significant difference in discomfort between his own wheelchair and TestChair2 with FeatureSet1.

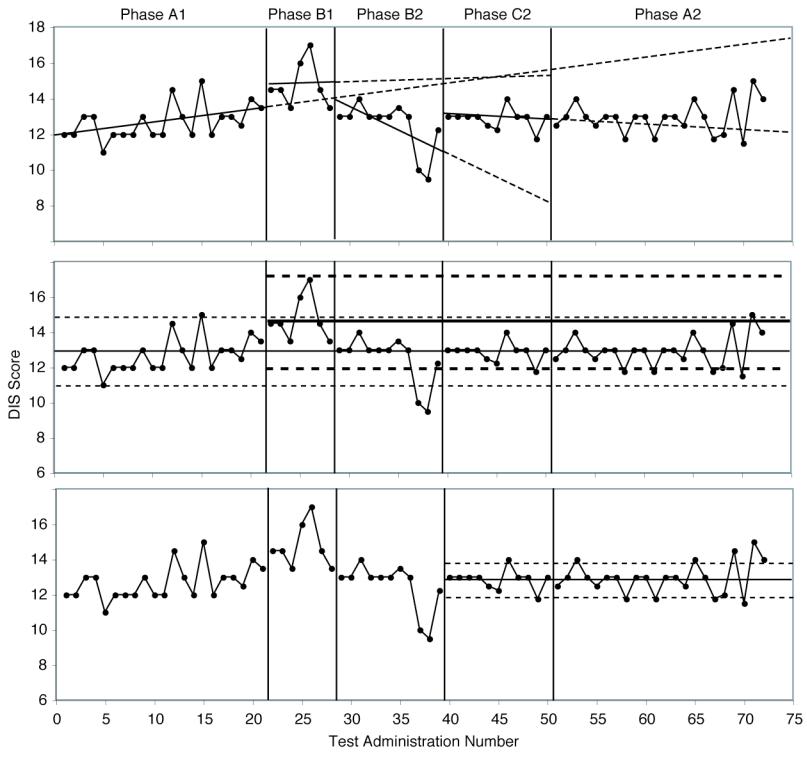


Figure 6-33: DIS score celeration lines and two standard deviation bands for Participant 2 (Upper panel shows celeration lines from Phase A1, B1, B2, and C2 trend lines. Middle panel shows mean and two standard deviation band lines for Phase A1 and Phase B1 (bold) data. Lower panel shows mean and two standard deviation band lines for Phase C2 data)

Visual comparison of the Phase B1 data with the Phase B2 data indicated differences in both means and trends for these two phases (see Figure 6-32). The mean DIS score was substantially higher when this participant used TestChair1 with FeatureSet1 than when he used TestChair2 with FeatureSet1. The trend of the data was also reversed – the TestChair1 data had a slight positive slope – indicative of an increasing discomfort level during this phase, and the TestChair2 data had a much steeper negative slope – indicative of a declining discomfort level when this participant used TestChair2 with FeatureSet1. The celeration line comparison of Phase B1 with B2 failed to reach a significant level because there were too few data points

during phase B2, even though all of the data points collected fell below the celeration line. However the two standard deviation band result indicated a significantly lower discomfort score for Participant 2 when he used TestChair2 with FeatureSet1 than when he used TestChair1 with FeatureSet1 (See Figure 6-33). Additionally, the C Statistic comparison of these two phases was significant (Z = 3.0) also indicating significantly lower discomfort when he was using TestChair2.

Phase C2: Intervention, Condition 5 (TestChair2, FeatureSet2)

During Phase C2 testing, the mean DIS score was 12.9 (SD = 0.2). Visual analysis of these data revealed no difference in mean level between Phase A1 and Phase C2, but the trends for these two data sets had reversed slopes. The Phase A1 data had a slight positive slope and the Phase C2 data had a slight negative slope – indicating a declining discomfort level during Phase C2 testing. Celeration line comparison of the phase A1 and C2 data indicated a significantly lower discomfort level in TestChair2 with FeatureSet2 than that experienced in this participants own wheelchair. The more rigorous two standard deviation band analysis, however, failed to indicate any significant difference in discomfort between these two wheelchairs. In agreement with the two standard deviation band, the C Statistic also failed to indicate any significant difference in discomfort level (Z = 0.36).

In the comparison of phases B1 and C2 data, visual analysis indicated a difference in means and a slight difference in trends between these two phases. The mean of the Phase C2 data was lower – indicating a lower discomfort level, and the trend of the data had a slightly negative rather than a slightly positive slope – indicating a decreasing discomfort level rather than an increasing one. As with the comparison of phase B1 and B2, the celeration line comparison of phase B1 and C2 failed to reach significance because of the lack of an adequate

number of observations during Phase C2, even though all observations present fell below the celeration line. The two standard deviation band analysis of phases B1 and C2 was also not significant. In spite of these results, the more rigorous C Statistic comparison of phase B1 and C2 data was significant (Z = 2.69) indicating a significantly lower discomfort level when this participant was using TestChair2 with FeatureSet2 than when he used TestChair1 with FeatureSet1.

Visual comparison of the means and trends for phases B2 and C2 indicated very little difference in phase means, but a substantial difference in trends for these data. The Phase B2 data had a trend with a very steep negative slope and the phase C2 data trend had only a slight negative slope. This indicated a much less dramatic decline in discomfort level during the Phase C2 testing as compared with the Phase B2 test phase. Celeration line comparison of phase B2 and phase C2 data indicated significantly higher DIS scores during Phase C2, or significantly higher discomfort when this participant used TestChair2 with FeatureSet2 than when he used TestChair2 with FeatureSet1. The two standard deviation band comparison of phases B2 and C2 was not significant, indicating no differences in discomfort level experienced when using these two different feature sets, however the C statistic, which assesses both mean and trend differences (Tryon, 1982), was significant (Z = 1.72), most likely indicating a significant difference in the trend of the two data sets – with the phase B2 data revealing a rapidly declining discomfort rate and the phase C2 data not sharing this same trend.

Phase A2: Return to baseline, Condition 6

The mean DIS score for the return to baseline phase was 12.9 (SD = 0.9). Visual analysis indicated no detectable differences in mean levels and only a slight shift in trend between the Phase C2 and Phase A2 data. The trend for the return to baseline phase resumed a slight

positive slope – indicating an increasing level of discomfort within this phase. Both the celeration line and two standard deviation band analyses indicated significantly higher DIS scores on return to baseline (using his own wheelchair) than those recorded during the final intervention phase using TestChair2 with FeatureSet2, however the C Statistic comparison of phases C2 and A2 failed to reach a significant level ($Z = 1.15$), indicating no difference in discomfort mean or trends between these two wheelchairs.

Visual comparison of the two baseline phase – A1 and A2 – indicated very little difference in mean DIS and only a slight change in trend – from a steeper trend for the Phase A1 data to a shallower, but still positive sloping trend for the Phase A2 data. Celeration line comparison of these two phases indicated a significantly lower discomfort level during the return to baseline phase than during the first baseline – even though his chair was unchanged, however, neither the more rigorous two standard deviation band nor the C Statistic result ($Z = 0.75$) indicated any significant difference between the two baseline phases.

6.3.3.5 Participant 3

Phase A1: Baseline, Condition 1

For this baseline phase, the mean DIS score was 36.7 ($SD = 8.8$). These data appeared to be quite variable with a repeated daily pattern of low DIS scores in the morning progressing to higher scores at the end of each day. The trend of these data had a downward slope, indicating a decreasing discomfort level during this baseline phase. This participant was randomized to an ACBA design.

Phase C2: Intervention, Condition 5 (TestChair2, FeatureSet2)

The mean DIS score for Participant 3 when he was using TestChair2 with FeatureSet2 was 15.5 (SD = 5.5). Visual analysis of these data revealed a large difference in DIS mean but very little change in trend for these data compared with the baseline data (see Figure 6-34). All semi-statistical (see figure 6-35) and statistical analyses indicated a significantly lower level of discomfort when this participant was using TestChair2 with FeatureSet2 than when he was using his own wheelchair (C Statistic Z = 4.97).

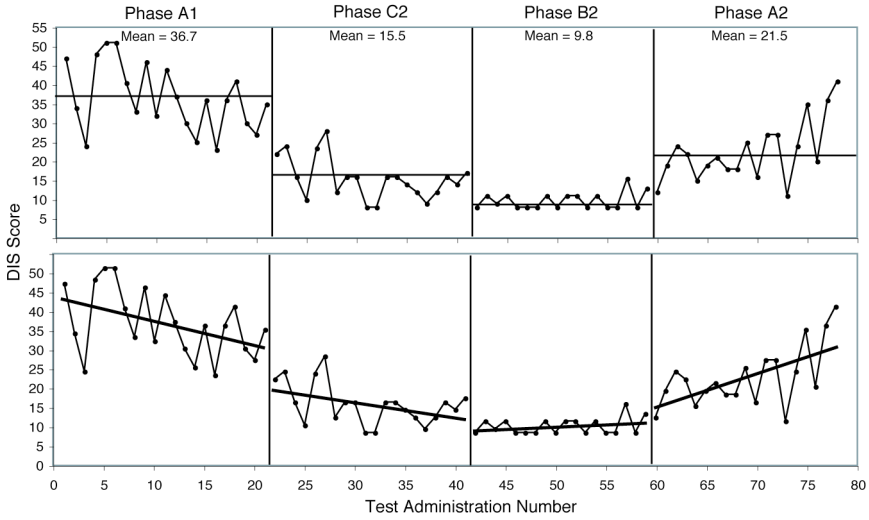


Figure 6-34: DIS score means and trends for Participant 3

Phase B2: Intervention, Condition 4 (TestChair2, FeatureSet1)

The mean DIS score for this condition was 9.8 (SD = 2.2). Visual analysis revealed a large difference between the baseline data (Phase A1) and the Phase B2 data in mean level and in trend. The mean for this discomfort measure was substantially lower when this participant used TestChair2 with FeatureSet1 than when he used his own wheelchair. The trends changed from a negative sloping trend during the baseline phase to a slight positive slope during Phase B2 – indicating a slightly increasing discomfort level when he was using TestChair2 with FeatureSet1. Both the celeration line and two standard deviation band analysis revealed significant differences between the baseline (A1) data and the Phase B2 data (see Figure 6-35), indicating significantly lower levels of discomfort when he was using TestChair2 with FeatureSet1 than when he used his own wheelchair. The C Statistic analysis confirmed this finding of a significant difference between these two wheelchairs (Z = 5.20).

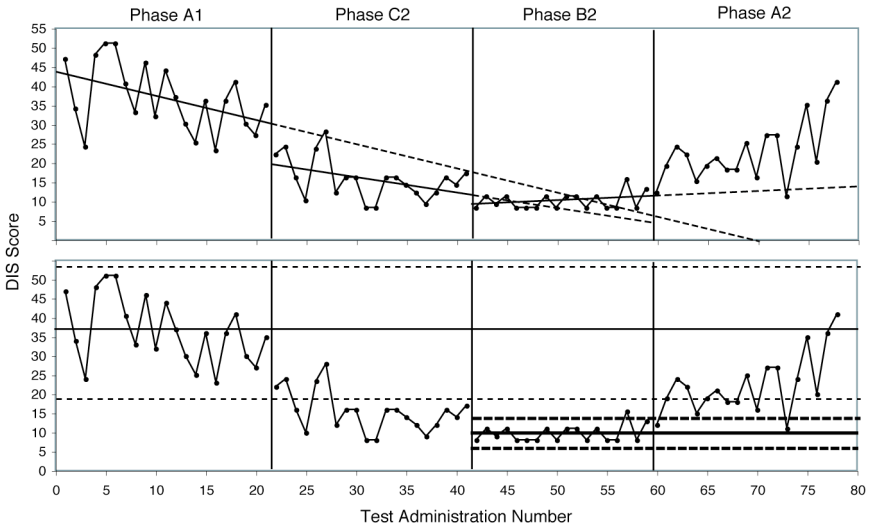


Figure 6-35: DIS score celeration lines and two standard deviation bands for Participant 3

(Upper panel includes celeration lines from Phase A1, C2 and B2 trends, lower panel includes mean and two standard deviation band lines for Phase A1 and Phase B2 (bold) data)

Analysis of Phase B2 data compared to Phase C2 data was also performed to determine the differential effects of FeatureSet1 and FeatureSet2. Visual analysis revealed a lower mean level under Phase B2 but a slight change in trend from a slight negative slope during Phase C2 to a slight positive slope – indicating increasing discomfort levels - during Phase B2 (when he was using FeatureSet1). Neither the celeration line nor two standard deviation band comparisons of phases B2 and C2 indicated a significant difference between his comfort level when using FeatureSet1 versus FeatureSet2, however, the C statistic comparison result was significant ($Z = 2.82$), indicating a difference in mean, or more likely in trend for his discomfort level while using these two feature sets.

Phase A2: Return to baseline, Condition 6

The mean DIS score for the return to baseline phase for this participant was 21.5 (SD = 8.0). Visual analysis of these data compared with the data from the preceding intervention phase (B2) indicated a difference in mean – with a higher DIS mean during the second baseline phase, and a change in trend. The trend of the Phase B2 data had a slight positive slope – indicating a slowly increasing discomfort level during this phase, however the trend of the return to baseline phase had a steep positive slope – indicating a rapidly increasing level of discomfort during this phase. Celeration line and two standard deviation band comparisons of Phase A2 and the preceding intervention phase (Phase B2) data indicated a significant increase in DIS scores when he returned to using his own wheelchair, indicating increased levels of discomfort. In addition, a C statistic analysis of the final intervention phase data and this baseline data (phase B2 and A2) was significant (Z = 4.35), again indicating a significant increase in his discomfort level when he returned to sitting in his own wheelchair.

Visual analysis of the Phase A2 data compared with the data from the first baseline phase (A1) indicated a difference in mean – with a lower DIS mean during the second baseline phase, and a reversal in trend. The trend of the Phase A1 data had a negative slope – indicating a declining discomfort level during this phase, and the trend of the Phase A2 data had a steep positive slope – indicating a rapidly increasing level of discomfort during this phase. The celeration line comparison of these two baseline phases indicated a significantly higher discomfort level during the return to baseline phase (A2) than that experienced during the first baseline (A1). However, the two standard deviation band indicated a significantly lower discomfort level during the second baseline phase (A2). This conflicting result was most likely due to the reversal in trends between these two phases. The C Statistic comparison of these data was also significant (Z = 3.48) reflecting both the change in mean level and in trend and indicating a lower overall discomfort level during the return to baseline phase (A2).

6.3.3.6 Participant 4

Phase A1: Baseline, Condition 1

For Participant 4, the mean DIS score when seated in his own wheelchair was 16.8 (SD = 4.8). There was a high degree of variability at the beginning of the baseline phase with a trend that had a slightly negative slope, indicating a decline in discomfort level during this phase. This participant was randomized to an ABCA design.

Phase B2: Intervention, Condition 4 (TestChair2, FeatureSet1)

For Phase B2, the DIS mean was 20.3 (SD = 3.9). Visual analysis of these data indicated a higher mean level than that of the baseline data and an increasing rather than a decreasing trend (see Figure 6-36). The result of the celeration line analysis indicated a significantly higher discomfort score when he was using TestChair2 with FeatureSet1 compared with his own

wheelchair (see Figure 6-37), however neither the more rigorous two standard deviation band nor the C Statistic results were significant (Z = 0.39), indicating no difference in discomfort level for this participant seated in his own wheelchair compared with when he was seated in TestChair1 with FeatureSet1.

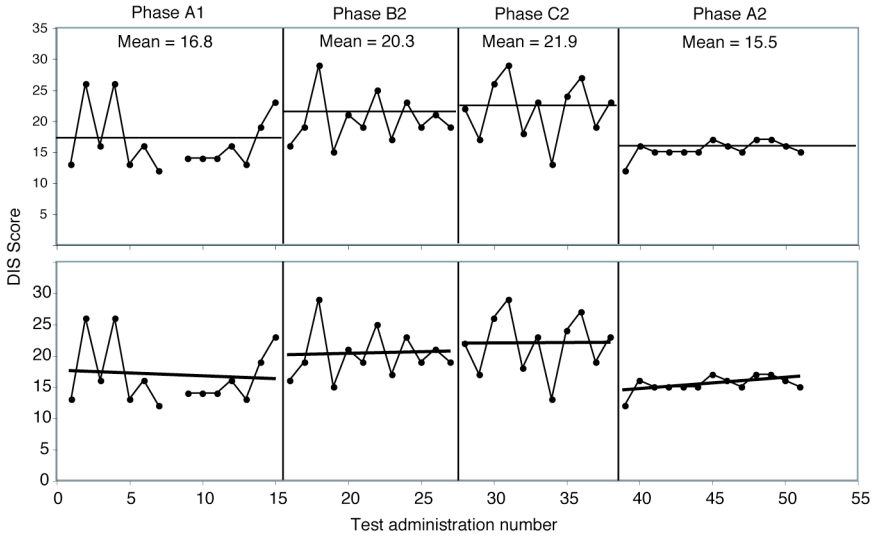


Figure 6-36: DIS score means and trends for Participant 4

Phase C2: Intervention, Condition 5 (TestChair2, FeatureSet2)

The mean DIS score for Phase C2 was 21.9 (SD = 4.8). Visual analysis again revealed a high degree of data variability and a higher mean level than that of the baseline data (Phase A1) with a very similar trend slope (see Figure 6-36). The celeration line analysis indicated a significantly higher level of discomfort when he was using TestChair2 with FeatureSet2 than that when he was using his own wheelchair (see Figure 6-37), however, as with the Phase B2 analysis, the more rigorous tests – the two standard deviation band and C Statistic (Z = 0.68) failed to indicate any difference in discomfort levels between this participant's own wheelchair and TestChair2 with FeatureSet2.

Comparison of the two intervention phases – B2 and C2 revealed no substantial difference in mean or in trend upon visual analysis (see Figure 6-36). Neither the celeration line nor the two standard deviation band analysis indicated any significant difference in discomfort level between use of FeatureSet1 and FeatureSet2, however, the C Statistic comparison of these two phases yielded a significant result (Z = 1.70), indicating a difference between the two intervention conditions.

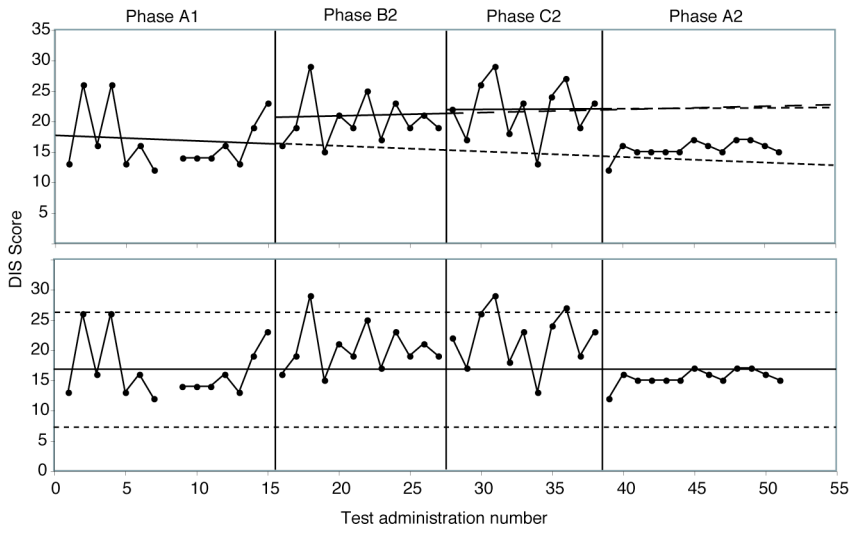


Figure 6-37: DIS score celeration lines and two standard deviation bands for Participant 4

Phase A2: Return to baseline, Condition 6

When Participant 4 resumed sitting in his own wheelchair, his mean DIS score was 15.5 (SD = 1.3). Visual comparison of the final intervention phase (C2) and this return to baseline phase (A2) indicated a drop in mean DIS score when he resumed using his own wheelchair. The trend remained very similar, with only a slight increase in the slope noted during Phase A2. Celeration line analysis indicated a significantly lower discomfort level in his own wheelchair than in TestChair2 with FeatureSet2, but this result was not found when employing the two standard deviation band or C Statistic analysis methodology (Z = 1.40), failing to indicate any significant difference in discomfort level when he returned to his own wheelchair.

When an a visual comparison of the two baseline phases (A1 and A2) was performed, the DIS means were very similar, with a slightly lower mean during the return to baseline phase, and the trends were also quite similar in slope, but opposite in direction. The Phase A1 trend had a slight negative slope – indicating a declining discomfort level during this phase, but the Phase A2 trend had a slight positive slope – indicating an increasing discomfort level during this phase. The Phase A2 data were also far less variable than those in Phase A2 – perhaps due to increased familiarity with the data collection instrument. The celeration line comparison of phase A1 and A2 data indicated a significantly higher discomfort level during the return to baseline phase than what would have been predicted from the original baseline (Phase A1). Neither the two standard deviation band nor the C Statistic indicated any difference in discomfort levels between these two baseline phases (Z = 0.86).

6.3.3.7 Participant 5

Phase A1: Baseline, Condition 1

The baseline mean DIS score for this final participant was 45.29 (SD = 2.1). Due to the significant result from the Bartlett test for autocorrelation for the Phase A2 data, all data from this participant was considered serially dependent (Ottenbacher, 1986) and the C-Statistic was relied on for testing of significance of these data across all phases. This participant was assigned to an ACBA test order.

Phase C2: Intervention, Condition 5 (TestChair2, FeatureSet2)

The Phase C2 mean DIS score was 33.44 (SD = 6.45). The C statistic comparison of Phase A1 and Phase C2 data was significant (Z = 3.59), indicating a change in discomfort between these two phases – in this case due in part to a lower discomfort mean score and a change in the trend of the data (both are detected by the C Statistic). This result indicated a significantly lower discomfort level when this participant used TestChair2 with FeatureSet2.

Phase B2: Intervention, Condition 4 (TestChair2, FeatureSet1)

The mean DIS score for Phase B2 was 47.1 (SD = 3.8). The C Statistic comparison of Phase B2 with the baseline phase (A1) was not significant (Z = 0.29), indicating no difference in mean discomfort level or trend between her own wheelchair and TestChair2 with FeatureSet1. The C Statistic comparison of discomfort level using TestChair2 with FeatureSet1 (Phase B2) with that when using TestChair2 with FeatureSet2 (Phase C2) was significant (Z = 3.67), indicating a significant difference in discomfort level experienced between use of FeatureSet1 and FeatureSet2. This result indicates that Participant 5 experienced significantly greater levels of discomfort when using FeatureSet1 than when using FeatureSet2, both on TestChair2.

Phase A2: Return to baseline, Condition 6

The Phase A2 DIS data for this participant were found to be serially dependent. The mean score for these data was 51.2 (SD = 6.73). C Statistic comparison of Phase B2 and Phase A2 data was not significant (Z = 1.57) indicating no differences between her discomfort levels when using TestChair2 with FeatureSet2 and her return to baseline wheelchair. C Statistic comparison of Phase A1 and Phase A2 data was also not significant (Z = 0.01) indicating no difference in discomfort levels between these two baseline conditions. Graphed data for this participant are presented in Figure 6-38 but were not used during these analyses due to the presence of serially dependent data for Phase A2.

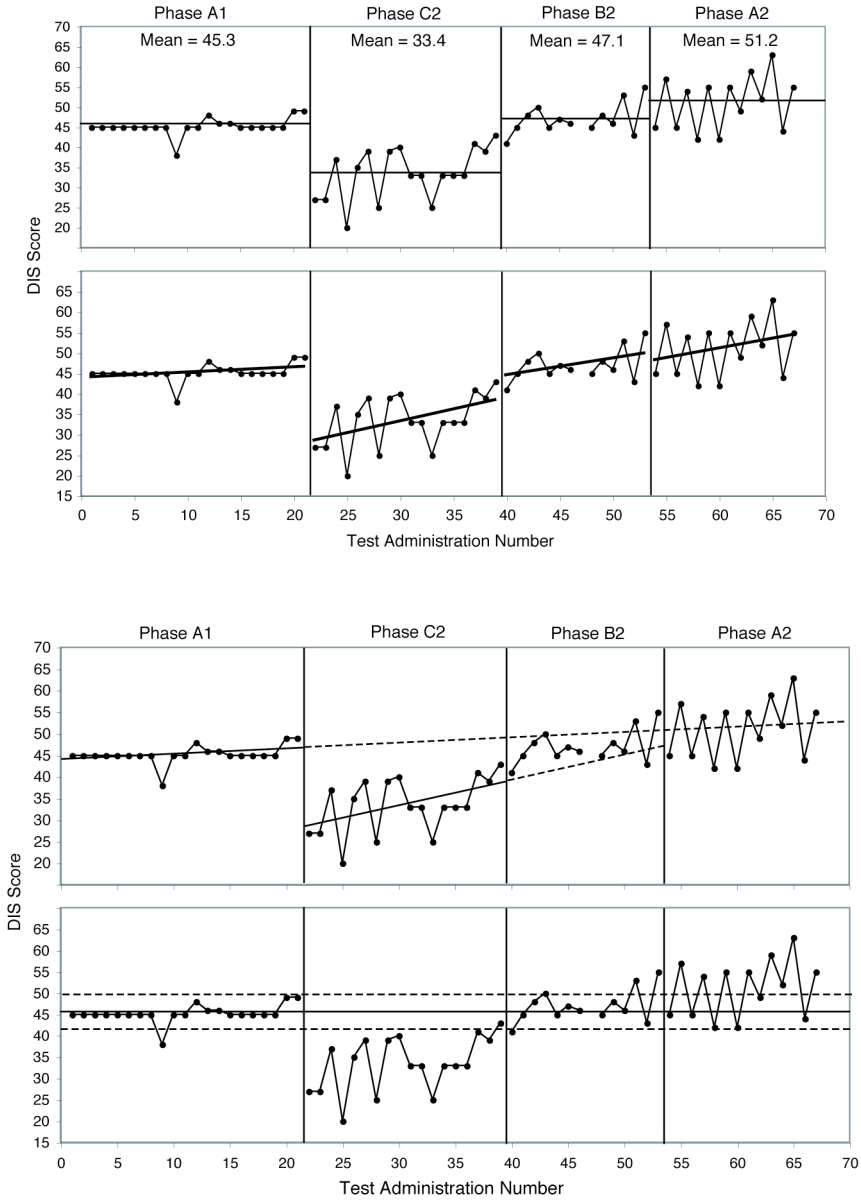


Figure 6-38: DIS score graphed data for Participant 5

(Top frame – mean levels and trends, bottom frame – celeration line and two standard deviation bands)

Table 6-9: DIS score summary of results

Participant and type of comparison	Comparison	Celeration line	Two standard deviation band	C-Statistic		
		*SIG***	*SIG***	Z Score	*p*	*SIG***
Participant 1: (ACBA design)						
Baseline ⟂ Intervention	A1 ⟂ C1	†	†	0.54*	0.2946	NS
Baseline 1 ⟂ Baseline 2	A1 ⟂ A2	†	†	2.06*	0.0197	SIG
Participant 1a: (ACBA design)						
Baseline ⟂ Intervention	A1 ⟂ C2	NS	NS	1.18	0.1190	NS
Baseline ⟂ Intervention	A1 ⟂ B2	SIG lower	SIG lower	2.55	0.0054	SIG
Intervention ⟂ Intervention	C2 ⟂ B2	NS	NS	2.78	0.0027	SIG
Intervention ⟂ Baseline	B2 ⟂ A2	SIG higher	SIG higher	2.37	0.0089	SIG
Baseline 1 ⟂ Baseline 2	A1 ⟂ A2	NS	NS	1.47	0.0708	NS
TestChair1 and TestChair2 (Participant 1):						
Intervention ⟂ Intervention	C1 ⟂ C2	SIG lower	SIG lower	2.58	0.0049	SIG
Intervention ⟂ Intervention	C1 ⟂ B2	SIG lower	SIG lower	3.72	< 0.001	SIG
Participant 2: (ABCA design)						
Baseline ⟂ Intervention	A1 ⟂ B1	SIG higher	SIG higher	2.53	0.0057	SIG
Baseline ⟂ Intervention	A1 ⟂ B2	SIG lower	SIG lower	1.45	0.0735	NS
Intervention ⟂ Intervention	B1 ⟂ B2	Not enough data points	SIG lower	3.00	0.0013	SIG
Baseline ⟂ Intervention	A1 ⟂ C2	SIG lower	NS	0.36	0.3594	NS
Intervention ⟂ Intervention	B1 ⟂ C2	Not enough data points	NS	2.69	0.0036	SIG
Intervention ⟂ Intervention	B2 ⟂ C2	SIG higher	NS	1.72*	0.0427	SIG
Intervention ⟂ Baseline	C2 ⟂ A2	SIG higher	SIG higher	1.15	0.1251	NS
Baseline 1 ⟂ Baseline 2	A1 ⟂ A2	SIG lower	NS	0.75	0.2266	NS
Participant 3: (ACBA design)						
Baseline ⟂ Intervention	A1 ⟂ C2	SIG lower	SIG lower	4.97	< 0.001	SIG
Baseline ⟂ Intervention	A1 ⟂ B2	SIG lower	SIG lower	5.20	< 0.001	SIG
Intervention ⟂ Intervention	C2 ⟂ B2	NS	NS	2.82	0.0024	SIG
Intervention ⟂ Baseline	B2 ⟂ A2	SIG higher	SIG higher	4.35	< 0.001	SIG

Table 6-9 (continued)

Participant and type of comparison	Comparison	Celeration line	Two standard deviation band	C-Statistic		
		*SIG***	*SIG***	*Z* Score	*p*	*SIG***
Baseline 1 → Baseline 2	A1 → A2	SIG higher	SIG lower	3.48	0.0003	SIG
Participant 4: (ABCA design)						
Baseline → Intervention	A1 → B2	SIG higher	NS	0.39	0.3483	NS
Baseline → Intervention	A1 → C2	SIG higher	NS	0.68	0.2483	NS
Intervention → Intervention	B2 → C2	NS	NS	1.70*	0.0446	SIG
Intervention → Baseline	C2 → A2	SIG lower	NS	1.40	0.0808	NS
Baseline 1 → Baseline 2	A1 → A2	SIG higher	NS	0.86	0.1949	NS
Participant 5: (ACBA design)						
Baseline → Intervention	A1 → C2	†	†	3.59	0.0002	SIG
Baseline → Intervention	A1 → B2	†	†	0.29	0.3859	NS
Intervention → Intervention	C2 → B2	†	†	3.67	0.0001	SIG
Intervention → Baseline	B2 → A2	†	†	1.57	0.0582	NS
Baseline 1 → Baseline 2	A1 → A2	†	†	0.01	0.4960	NS

* Comparison series used for analysis

** Significance at the $p < 0.05$ level

† Analyses not used for this participant due to the presence of serially dependent data

6.4 DISCUSSION

As the results presented in the preceding sections and summarized in tables 6-5, 6-7 and 6-9 indicate, the three measures considered to be related to discomfort – time spent sitting in one's wheelchair (TIC), and the WcS-DAT GDA and DIS discomfort scores performed very differently from each other and across participants in this study. A hierarchical approach to analysis of these data was used – starting with the most basic single subject design method of visual analysis. Following autocorrelation testing, three semi statistical and statistical approaches were then used in increasing level of rigor. The first of these was the celeration line method, the next was the two standard deviation band and the final and most rigorous test was the C Statistic. Performance of each of the outcome measures (TIC, GDA, and DIS), of the methodology applied, and of the user adjustable seating was evaluated based on the outcomes and level of agreement of all of these analysis methods. Consideration was also given to the agreement of data analysis with anecdotal reports from the participants themselves.

The time in wheelchair, or TIC, data were the most inconsistent across the conditions, with only 7 phase-to-phase analyses having full agreement on all methods, and TIC also showed the fewest total phase comparison significant results (32 of 99 total). One advantage of these data was that they were least likely to be autocorrelated – with none of the participants' phases testing positive for serial dependency. There were too few points for celeration line analysis for Participant 2, Phase B1 due to the interruption of testing. Both participants 1 and 2 reported significantly increased discomfort using TestChair1 (phases B1 and C1), but the time they spent sitting was not significantly different from that when using their own wheelchairs. Participant 3, who demonstrated significantly decreased discomfort levels using TestChair2 on both the GDA and DIS measures, also had mixed results on all tests of his TIC data – two of which indicated

significantly less sitting time and one significantly more. Because of the low frequency of data points, typically 6 –7 per phase, the baseline trend lines may not have been very accurate representations of true sitting time behavior (Ottenbacher, 1986).

Another problem with the measure of sitting time is that participants tested in this study had little ability to control how long they sat each day. Only two of the participants (participants 3 and 5) could transfer independently, all the others relied on other family members or personal care attendants to assist them with transfers. Their sitting schedules were largely determined by the schedules of those around them and their own activities for the day (e.g. for Participant 1, a college student, his class schedule). They were not typically able to alter these sitting schedules when they became uncomfortable. For this reason, total sitting time did not perform well as an indication of wheelchair seating discomfort among these participants. For populations with higher levels of discomfort – high enough to demand action – this may not hold true and discomfort may indeed limit sitting time, but this was not the case with the participants tested in this study.

The GDA scores performed more consistently, particularly in the cases of clearly increased or decreased discomfort levels. There were 40 significant results, 9 of which were excluded due to the serially dependent data, leaving 31 significant out of 77 total analyses. Additionally, 10 of the phase to phase comparison combinations had full agreement across all analysis methods. Two of the participants had serially dependent data on this measure, therefore the C Statistic was relied on for these analyses. Participant 3 reported dramatically lower levels of discomfort while using TestChair2 and his GDA scores showed significantly lower discomfort levels on all analyses. Conversely, Participant 2 indicated increased discomfort when using TestChair2, and although his increased discomfort levels were not as pronounced, his GDA data

demonstrated significantly higher levels of discomfort on 2 out of the 4 analyses. Overall, the four analysis methods had better agreement as to significance or non-significance for the GDA data than for the TIC data.

The final measure used – the DIS scores – was the best of the three in terms of overall significance (55 total significant results, 7 of which were excluded due to serially dependent data – leaving 48 significant results out of 85 total analyses) and level of consistency across analysis methods (11 full phase to phase comparison agreements). As with the GDA scores, this measure resulted in serially dependent data for two of the participants. Due to the previously noted dramatic change in discomfort level, DIS data from Participant 3 indicated significant results across all treatment phases and across all analysis methods. Data from Participant 1a were also significant for all analysis methods for comparison of Phase A1 and Phase B2 and not significant across all methods comparing Phase A1 and Phase C2. Visual analysis was simpler for these data as well due to the decreased variability of the data.

Both the DIS scores and the GDA scores related closely to the participants' anecdotal reports of increased or decreased discomfort levels. Comparisons of the test wheelchair with the baseline wheelchair and TestChair1 to TestChair2 were facilitated by both the GDA and DIS measures. For all participants, the DIS and GDA measures were sensitive to differences between their own wheelchairs and the test wheelchair in use. Most of these differences showed decreased discomfort levels when using the user adjustable features available on the test wheelchair. These differences were particularly dramatic as the differences between the features available on the participants' own wheelchairs and those available on the test wheelchair differed (e.g. Participant 3 who had very few adjustments available on his own wheelchair). For the two participants who trialed TestChair1 and TestChair2 (participants 1 and 2), both the GDA and

DIS measures, in contrast to the earlier TIC measure, were able to differentiate the discomfort differences between these two wheelchairs – which were anecdotally reported by both of these participants. However the GDA and DIS measures did not seem to be sensitive enough in many cases to allow comparison of the two treatment phases using different configurations of seating (FeatureSet1 and FeatureSet2). This may be due to the lack of a differential effect of the two feature sets – i.e. the addition of the pneumatic features did not produce enough of an effect on discomfort to allow these measures to detect differences between these two intervention phases (B and C) in most cases.

6.5 CONCLUSION

This study examined the effectiveness of the WcS-DAT and the sitting time outcome measures for detecting differences in discomfort levels over time, or with the introduction of different seating equipment. Also, the research methodology used in this study, single subject design, was a novel approach to studying discomfort and the effects of a user adjustable seating intervention in this population. The effectiveness of the intervention – the user adjustable wheelchair seating – was also examined to guide future development of this type of equipment to address the issues around discomfort.

As indicated, the time in wheelchair outcome measure did not perform well as a measure of wheelchair seating discomfort. The results based on this measure were inconsistent and difficult to assess due to the problems with small data sets and the scheduling realities faced by the participants involved in this study. This may be an important measure for other individuals with seating discomfort, but it did not prove itself during this research. Conversely, the two scales included in the WcS-DAT performed adequately based on consistency across analysis methods and for measuring differences in discomfort levels over time and with the introduction

of the wheelchair seating interventions. Although these measures had difficulty detecting very small treatment effects (i.e. the difference between the B and C phase interventions) they easily detected differences from the baseline seating (the participant's own wheelchair) to the test wheelchairs.

Finally, as to the effectiveness of the research design as a whole, the single subject research design allowed insight into this very difficult wheelchair seating problem. The 28-day (sometimes longer) labor intensive data collection methodology placed great demands on the participants in this study. There were some inconsistencies with the data collected due to recording errors or difficulties recording data on the recommended schedule, but overall the data collected allowed the in-depth investigation of discomfort as a wheelchair seating problem and the effectiveness of a potential intervention (the user adjustable seating).

Discomfort levels were shown to increase throughout the day – particularly after 6 hours of continuous sitting. These data validated the effectiveness of the WcS-DAT tool and reinforced the need for long duration testing of wheelchair seating products to truly determine their ability to combat sitting discomfort. Also, discomfort levels fluctuated from day to day, indicating a need for multi-day evaluations to truly determine consistency of performance. The 7-day phases required tremendous dedication from the participants, but resulted in a richness of data unavailable with shorter testing periods and in some cases (e.g. sitting time measures), longer phases might have been more desirable.

The difficulties involved in introducing a novel wheelchair to these participants cannot be overlooked. The wheelchair base itself, which was not being studied, may have interfered with the ability to truly examine the effects of the seating intervention. The fit and function of the wheelchair was sub-optimal for many of the participants and interfered with true testing of the seating intervention being studied.

Recommendations for future study include: 1) studying "stand-alone" seating products that would be capable of integrating into the participants' own wheelchairs; 2) reducing the WcS-DAT scoring to perhaps twice per day – once at 6 hours and once at bed time – due to the relatively low levels of discomfort reported with shorter sitting durations; 3) reducing the data collection labor involved on the part of the participants (perhaps by automating more of the data collection process) and extending the phase lengths to 8 – 10 days per phase to attain greater stability of trends; and 4) increasing the number and pattern of alternating phases – perhaps only studying one intervention at a time and using an ABABA design. These changes will enhance the ability of the WcS-DAT to evaluate the impact of wheelchair seating on the outcomes of discomfort.

7.0 SUMMARY AND RECOMMENDATIONS

7.1 REVIEW OF OBJECTIVES

The main goal of this dissertation research was the development and validation of a tool for quantifying wheelchair seating discomfort in sensate wheelchair users. This main goal was accomplished progressively through attainment of several smaller goals:

1. To use input from wheelchair users who have experienced discomfort to develop the content of a tool that is useful in allowing individuals who use wheelchairs to quantify their level of discomfort. (Pilot studies and Phase I)
2. To assess the reliability, concurrent validity and internal item consistency of this tool to allow it to be a valid research tool for the stated purpose. (Phase II)
3. To assess the effectiveness or sensitivity of this tool for detecting changes in wheelchair seating discomfort elicited in a longitudinal study using a prototype user adjustable wheelchair seating system. (Phase III)

To accomplish these goals, three major research studies and two smaller, preliminary research studies were carried out. The results from each of these research tasks have been presented in earlier chapters of this dissertation and discussed within these individual chapters. This chapter will summarize and discuss all of these research tasks and the overall results and conclusions of this research as a whole. Limitations of the research tasks will be discussed as well as recommendations for future research to expand on that presented in this dissertation.

7.2 SUMMARY OF FINDINGS

To accomplish the goal of developing a valid and reliable wheelchair seating discomfort assessment measure, the first step was to perform an extensive review of the literature to determine what assessment measures already existed that would help guide the development of the WcS-DAT. This literature review is presented in full in Chapter 2 of this dissertation. Results of this review are as follows: (1) as suspected, no validated tool for assessing wheelchair seating discomfort currently exists; (2) there have been multiple tools developed and validated for assessing seating discomfort among unimpaired users of office equipment and automobiles, but these do not directly relate to the unique problems encountered by wheelchair users, (3) wheelchair users do experience discomfort associated with sitting in their wheelchairs and it is a significant and negative outcome of this type of assistive technology use, and (4) due to the potential size of the population of wheelchair users likely to experience problems related to wheelchair seating discomfort, a tool that will aid in research, clinical outcomes measurement, and product design and testing would be highly beneficial.

Results from the two pilot studies helped to confirm the significance of the seating discomfort problem and also helped to guide the development of the WcS-DAT and of the user adjustable wheelchair seating system used in the Phase III testing process. In Pilot Study 1 a questionnaire was used (see Appendix A) to query representatives of the target population regarding their experiences with wheelchair seating discomfort. Nine individuals completed this extensive survey process and data were collected regarding the most important attributes of wheelchair seating systems, the importance of adjustability of various wheelchair seating components, and the problems associated with long duration (over 8 hours per day) wheelchair use. Several results found in the literature regarding the importance of comfort for wheelchair

users and the current comfort-related limitations of the available wheelchair seating products were re-confirmed by the data collected. The results from this small pilot study supported the need for a more in-depth investigation of this topic and guided the initial development of the discomfort assessment tool later developed during Phase I of the larger research study. In Pilot Study 2 a prototype of a user adjustable wheelchair seating system was introduced in a laboratory-based study to assess the initial response to the various adjustable components by a group of experienced wheelchair users also from the target population. This limited trial of many user adjustable components provided valuable information regarding the importance of adjustability of various features and helped to guide the development of the next prototype test wheelchair seating system (PTS2). This interaction with the subjects also added to the general knowledge of discomfort problems and possible solutions. Overall the response of these participants was extremely positive and further encouraged and supported the research proposed in phases I, II and III of this dissertation.

Phase I of the main research associated with this dissertation involved the use of qualitative research techniques to obtain necessary information to construct the Wheelchair Seating Discomfort Assessment Tool (WcS-DAT). This research phase involved interviews with experienced wheelchair users who all had problems with seating discomfort. The interview questions explored the wheelchair users' experiences of discomfort and comfort, strategies for management of discomfort or pain, and differences between comfort and discomfort and pain and discomfort. The data from these interviews were coded and analyzed and the analysis was used to generate the three components of the WcS-DAT. Part One of the WcS-DAT asks several questions all related to factors felt to influence the development of discomfort by the wheelchair users who were interviewed. This section includes items such as being transferred properly into

one's wheelchair, the duration of sitting, distraction in one's environment, the effects of vibration caused by traveling over rough terrain in one's wheelchair, and several other similar items. Part two of the WcS-DAT asks the wheelchair user to rate the level of agreement or disagreement with 13 statements related to comfort and discomfort on a 7 point Likert scale. All of these statements were generated directly from the statements offered by the wheelchair users during the Phase II interview process. The final part of the WcS-DAT – Part III – allows the wheelchair users to rate a level of discomfort on a 0 to 10 scale of several body areas and of the body as a whole. The necessity of this part of the tool was suggested by the tools reviewed during the literature review (Corlett & Bishop, 1976; Helander & Zhang, 1997), but also by the participants in the interview process. The body area list was generated directly from the data obtained during the interviews. Following the construction of this tool, it was distributed to the individuals who participated in the interview for a "member checking" process. This was a way to confirm the face validity of the tool and to assure that it was representative of what the participants felt they conveyed during the interview process. All of the participants were pleased with the final tool and all felt it represented their experiences of wheelchair seating discomfort and would be a good way to assess wheelchair seating discomfort. Triangulation with other sources (literature reviewed and expert clinicians) also confirmed the initial validity of the WcS-DAT.

In Phase II of this research, 30 subjects were recruited to participate in a test-retest reliability and concurrent validity study of the WcS-DAT. These subjects were provided with four copies of the WcS-DAT as well as copies of the Chair Evaluation Checklist (Helander & Zhang, 1997) and the Short Form of the McGill Pain Questionnaire (Melzack, 1987). The subjects completed these assessments in pairs. The first pair was completed the day of enrollment in the study – one hour apart from each other. The second pair was completed one

week later at approximately the same time of day and also one hour apart. This time schedule was designed to provide optimal similarity in wheelchair seating discomfort levels, realizing that wheelchair seating discomfort is not stable by its nature. Intraclass Correlation Coefficients (ICC) were used to assess the reliability of the two discomfort scores derived from the WcS-DAT data – the General Discomfort Assessment score (GDA) and the Discomfort Intensity Score (DIS). The resulting ICC's ranged from a low of 0.83 to a high of 0.97. The pre-determined criteria of acceptability was 0.80, so all of the ICC scores met or exceeded the established criteria for adequate reliability. Internal consistency of the items was assessed using Cronbach's Alpha scores. These scores ranged from 0.82 to 0.92 for each of the individual items. These values indicated good internal consistency without redundancy of items. Due to these results, the decision was made that no changes to the content of the WcS-DAT were indicated. Pearson product moment correlations were used to assess concurrent validity of the WcS-DAT with the other tools used in this assessment process. Of 52 comparisons used for determining concurrent validity, 45 of them were significant at the 0.001 level, six were significant at the 0.01 level and one was significant at the 0.05 level. These results indicated good concurrent validity of the WcS-DAT with similar tools that have already been validated with different subject populations. However, the resulting correlations were not strong enough to suggest that the measures used for this concurrent validity assessment would be adequate tools to assess wheelchair seating discomfort – a slightly different construct.

In phase III of this research, the WcS-DAT was used to assess changing levels of discomfort in a prospective, longitudinal, single subject design study. This was a multiple baseline, alternating treatments design with an ABCA/ACBA format. The results from this study were used to analyze the effectiveness of the WcS-DAT in detecting changes elicited by

sitting duration and by use of a prototype user adjustable powered wheelchair seating system designed to reduce wheelchair seating discomfort. The results, extensively reported in Chapter 6 of this dissertation, illustrate the excellent performance of the two measures – the GDA and the DIS assessment scales – in quantifying wheelchair seating discomfort for the 6 single subject trials performed. These scores were sensitive to changes brought about by increased sitting duration and also were able to show changes based on the use of novel seating equipment – regardless of the direction of change. The two scores had good agreement with each other and good agreement across analysis methods used.

7.3 LIMITATIONS OF THIS RESEARCH

The research studies reported in this dissertation each have important limitations that affect the generalizability of the findings. All of the studies were restricted to a very specific target population – namely wheelchair users with intact sensory function and severe motor deficits. This target population was specifically selected due to the belief that the wheelchair users comprising this group would be at particularly high risk for wheelchair seating discomfort. This served two purposes – one was to recruit subjects with particular discomfort related experiences or expertise, the other is to assure that the findings would benefic those most affected by the problem. Diagnostic groups included multiple sclerosis, muscular dystrophy, amyotrophic lateral sclerosis, and polio or post polio syndrome. Due to these restrictions, the applicability of the WcS-DAT in quantifying wheelchair seating discomfort for wheelchair users who are not a part of this population cannot be predicted. The first two pilot studies used very small numbers of subjects – nine for Pilot Study 1 and six for Pilot Study 2. Even if these self-selected subjects

were representative of the chosen target population, this small number of subjects may reduce applicability of these findings to other wheelchair users. During Phase I testing, the quality of the data collected may have been affected by the inexperience of the researcher. Even with the training and preparation provided by research mentors, the interviews would have been strengthened by having a more experienced qualitative researcher involved in the process. All of the phases involved the use of subjects or participants who were not randomly selected, but rather were self selected after seeing advertisements for this study or hearing about the study from another source. This introduces a selection bias in that there may have been some characteristic specific to those who volunteered to participate that affected how they reacted to the intervention. This does not provide conclusive evidence that these samples were not truly representative of the target population, but it must be kept in mind that many statistical techniques used rely on a basic assumption of random subject selection to allow generalization to the target population as a whole. This is not as much of a concern for Phases I and III – which do not rely on statistical methods founded on the principles of random selection, but may particularly affect Phase II. Another concern for Phase II and Phase III testing is the testing effects that may be introduced by completing the same assessment multiple times. During Phase II the WcS-DAT is completed on four occasions and the two pair are completed one hour apart. One of the risks to assessing the true reliability of the tool is that the subjects are merely remembering and repeating answers rather than re-assessing and providing answers based on their present experience. The complexity of the assessments completed would help to minimize this risk, but it still must be acknowledged. The repetitive testing involved in Phase III may well have led to an increased risk of testing effects in which the actual completion of multiple tests will affect the response being measured in the subjects (i.e. their discomfort levels may be

heightened or diminished by the act of the reporting itself). Phases II and III both involve discomfort testing on multiple occasions, which may affect the way in which the subjects report or attend to their sitting discomfort just because of the testing. For the Phase III study – which was carried out over approximately 28 days of testing per subject, history and maturation may have affected the results obtained. Many of the research subjects had progressive neuromuscular disease processes and they may have actually undergone changed in their medical or functional conditions (maturation) that would affect their level of seating discomfort. Also, several of the subjects underwent changes in their equipment usage or in their home environments or activities – history effects, that may have affected their discomfort levels separate from the independent variable.

During Phase III, there may have been a novelty affect associated with the introduction of a new wheelchair and seating system that the subjects were aware was supposed to alleviate seating discomfort. Although the subjects were not specifically informed of this, it was not possible to totally blind them to the intent. This may have affected their initial responses to the test equipment. It was hoped that the time frame chosen for testing i.e. one week per phase, would be long enough for this "novelty" affect to wear off – (by allowing a "wash in" period) but for some of the subjects this may have not been true and their responses to the equipment may have been based on the fact that it was new or different rather than that it was truly less uncomfortable.

7.4 CONTRIBUTIONS OF THIS RESEARCH

The research in this dissertation, presented in the preceding paragraphs, resulted in several contributions to the field of wheelchair seating research, particularly to that involving wheelchair seating outcomes or problems associated specifically with seating discomfort among wheelchair users. The most prominent contribution is that of the WcS-DAT – a validated tool for quantifying wheelchair seating discomfort. This type of tool has never been produced and validated for use with wheelchair seated individuals and the ability to use this tool for future research, measurement of clinical outcomes, and development of new wheelchair seating products is potentially revolutionary.

In addition to this major contribution have been several smaller but not less important contributions. The two pilot studies and the Phase I research contributed to our knowledge and understanding of the problem of discomfort in the target population. This research also focused on wheelchair seating discomfort from a consumer's perspective – this gave the researchers additional insight that was then shared with the research and clinical practice communities during conference presentations (Crane & Hobson, 2002; Crane et al., 2003). Also, in Phase III, a novel approach to studying wheelchair seat discomfort using a single subject design methodology was assessed and found to be a highly effective method for investigating wheelchair seating discomfort and the impact of assistive technology on discomfort.

7.5 RECOMMENDATIONS FOR FUTURE RESEARCH

The findings from this research, in the context of previous research found in the literature related to discomfort and wheelchair seating outcomes, suggest several possible areas for future research. Validation of the WcS-DAT tool with other populations of wheelchair users would increase its general usefulness as a clinical outcome and research tool. Further study of the many factors associated with wheelchair seating discomfort and possible assistive technology interventions that might ameliorate this difficult problem would also be highly beneficial. Using the WcS-DAT and the Phase III research design methodology, further investigation of the effectiveness of currently available technologies in preventing or minimizing wheelchair seating discomfort is also indicated. This may include investigation of powered seating technologies, such as powered tilt, powered recline, powered adjustable leg rests and others. This may be a highly valuable tool in determining and proving the efficacy of current as well as new technology interventions. In addition to the possible research applications, the WcS-DAT was designed to meet a need for a clinical outcomes measurement tool to assist with therapeutic decision making and determining the overall effectiveness of the processes and equipment currently in use in wheelchair seating service delivery settings. Widespread use of this discomfort assessment measure will assist clinicians and consumers by providing better evidence about the relative effectiveness of possible seating interventions in prevention of seating discomfort.

APPENDICES

APPENDIX A

SEATING COMFORT QUESTIONNAIRE – PILOT STUDY I

Part I. General Information

1. Date of this visit: _____/_____/_____
   month day year
2. Date of Birth: _____/_____/_____
   month day year
3. Primary Diagnosis:
   ___ (1) Amyotrophic Lateral Sclerosis (ALS)
   ___ (2) Multiple Sclerosis (MS)
   ___ (3) Muscular Dystrophy (MD)
   ___ (4) Polio or Post Polio Syndrome(PPS)
   ___ (5) Other, please specify: _____

4. Date of onset of this diagnosis: _____/_____
   month year

5. Do you have a secondary diagnosis?
   ___ (0) no
   ___ (1) yes --→ please check all that apply: ___ (1) Osteoarthritis
   ___ (2) Rheumatoid Arthritis
   ___ (3) Fibromyalgia
   ___ (4) Other, please specify:
   _____

6. What is the date of onset of this diagnosis? _____/_____

month year

7. What is your height? _____inches
8. What is your weight? _____pounds
9. Has your weight changed (increased or decreased) by 20 pounds or more over the past year?

___ (0) no

___ (1) yes

10. Describe your current seating system:

a. seat cushion type/brand: _____

b. back cushion type/brand: _____

c. Is there a tilt in space seating system:

___ (0) no

___ (1) yes -----→ is it ___ (2) power

___ (3) manual

d. Is there a reclining system present:

___ (0) no

___ (1) yes ----→ is it ___ (2) power

___ (3) manual

11. When did you obtain your current seating system: _____/_____

month year

12. What is your current mobility base:

___ (1) manual wheelchair

___ (2) power wheelchair

___ (3) three wheeled power scooter

___ (4) four wheeled power scooter

___ (5) other, please describe: _____

13. When did you obtain your current mobility base: _____/_____

month year

14. Do you have difficulties with bowel or bladder continence when you are sitting in your chair?

___ (0) no

___ (1) yes → does this occur:
- ___ (1) once a day
- ___ (2) once a week
- ___ (3) once a month
- ___ (4) other, please describe: _____

Part II. Functional level

1. On an average day, how long do you spend in your seating system? _____hours
2. What is a typical reason for getting out of your seating system? (check all that apply)

___ (1) discomfort

___ (2) fatigue

___ (3) functional need

___ (4) convenience of family or caregivers

___ (5) home health aide schedule

___ (6) other reason, please specify: _____

3. Type of transfer **usually** used to get in and out of your seating system: (check one)
   - ___ (1) stand and pivot
   - ___ (2) sliding board
   - ___ (3) mechanical lift assisted
   - ___ (4) lifted in/out by another person (or 2)
   - ___ (5) other, please describe: _____
4. Amount of assistance **usually** needed for this transfer: (please check one)
   - ___ (1) no outside assistance, no equipment
   - ___ (2) no outside assistance, equipment needed
   - ___ (3) minimal assistance of one person
   - ___ (4) moderate amount of assistance (I do about 1/2 of the work)
   - ___ (5) maximal amount of assistance of: one person
   - ___ (6) two people are needed to assist

5. Does your ability to transfer with this amount of assistance change:

a. during the day?

___ (0) no

___ (1) yes

b. from day to day?

___ (0) no

___ (1) yes

6. Does your ability to transfer depend on the set up of your chair?

___ (0) no

___ (1) yes --→ does it depend on (check all that apply):

___ (1) the height of the chair seat

___ (2) the "slipperiness" of the seat surface

___ (3) the firmness of the seat

___ (4) the flatness of the seat

___ (5) other, please specify: _____

7. What types of daily self care tasks are done in your chair? (check all that apply)

___ (1) bathing

___ (2) dressing

___ (3) shaving

___ (4) brushing teeth/washing face

___ (5) hair care

___ (6) meal preparation

___ (7) eating

___ (8) self catheterization

___ (9) other, please specify: _____

8. In what environments is your chair used?

___ (1) home

___ (2) school

___ (3) work

___ (4) other, please specify: _____

9. On an average weekday (Monday through Friday), what percentage of the time you spend in your chair is spent: (total must be 100%)

At home _____% At school _____% At work _____%

Other environment _____%: please describe environment _____

10. On an average weekend day (Saturday or Sunday), what percentage of the time you spend in your chair is spent: (total must be 100%)

At home _____% At school _____% At work _____%

Other environment _____%: please describe environment _____

Part III. Level of comfort in your current seating system

1. When you began using a wheelchair for at least 6 hours per day, did you have comfort problems?

___ (0) no

___ (1) yes

2. Since you obtained your present wheelchair seating system, have you been experiencing discomfort?

___ (0) no

___ (1) yes

3. In the past month, have you been uncomfortable in your current seating system?

___ (0) no

___ (1) yes -→ do you become uncomfortable: (check one)

___ (1) After a few hours

___ (2) every day

___ (3) once a week

___ (4) once a month

4. Do you ignore your discomfort in order to function at your current level?

___ (0) no

___ (1) yes

5. When you experience discomfort, where on your body is the discomfort experienced? (please circle all appropriate areas on the "body discomfort map" given to you)

6. Are you uncomfortable right now?

___ (0) no

___ (1) yes

7. How long have you been sitting in your seating system today? _____hours

8. How do you currently manage discomfort in your seating system?

___ (1) I get out of my seating system

___ (2) I take medications (prescription or non-prescription)

___ (3) I ask someone to re-position me in my seating system

___ (4) I re-position myself in my seating system

___ (5) I have no way to manage discomfort

___ (6) I use some other method, please describe:

_____

9. How often do you currently use the following features of your wheelchair seating system to manage discomfort? (please rate an average day)

Seating system feature	Not applicable (I don't have this feature on my wheelchair)	Number of times per hour	**OR**	Number of times per day
Power tilting system				
Power reclining system				
Power seat elevation system				
Other: Please describe				

10. How do you currently relieve pressure in your seating system?

___ (1) I get out of my seating system

___ (2) I use my tilt in space or recline system (if present)

___ (3) I ask someone to re-position me in my seating system

___ (4) I re-position myself in my seating system

___ (5) I have no way to manage pressure in my current seating system

___ (6) I use some other method to manage pressure, please describe:

11. How often do you currently use the following features of your wheelchair seating system to manage pressure? (please rate an average day)

Seating system feature	Not applicable	Number of times per hour	**OR**	Number of times per day
Power tilting system				
Power reclining system				
Power seat elevation system				
Other: Please describe				

12. Is your ability to sit in your seating system (total sitting time) limited by discomfort?

___ (0) no

___ (1) yes

13. Is your ability to perform functional activities in your seating system limited by discomfort?

___ (0) no

___ (1) yes

14. Please rate the effect that moving over bumpy surfaces in your chair has on your comfort?

___ (1) it makes me more uncomfortable

___ (2) it has no effect on my comfort

___ (3) it makes me less uncomfortable

15. Please rate the effect that just sitting still in your chair has on your comfort?

___ (1) it makes me more uncomfortable

___ (2) it has no effect on my comfort

___ (3) it makes me less uncomfortable

16. Do you have a history of skin breakdown?

___ (0) no

___ (1) yes --→please describe the following for the most recent episode:

location:_____

occurrence: _____months ago or _____years ago

17. Has this week been a typical week for you in terms of your level of comfort and your ability to function?

___ (0) no

___ (1) yes

Part IV. Your suggestions for improving seating system comfort

1. What is the one feature of your current seating system that makes you comfortable?

_____

2. What is the one feature of your current seating system that makes you uncomfortable?

_____

3. If you could design "the perfect" seating system, what features would you consider essential in the design?

_____

4. How important are these features of a seating system to you: (Please rate each of the following features using a 1-10 scale, 1 being least important and 10 being most important)

___ a. Comfort

___ b. Safety

___ c. Mobility

___ d. Ability to perform self care tasks

___ e. Independent use of all features

___ f. ability to adjust multiple features

___ g. ability for caregiver to adjust features

5. How important is it for you to be able to adjust or move the following features of your chair? (Please rate each of the following features using a 1-10 scale, 1 being least important and 10 being most important)

___ a. Arm rests

___ b. Leg rests

___ c. Lateral supports

___ d. Head support

___ e. Control Mechanism

___ f. seat temperature

___ g. seat belt

6. If the following parts of the chair could be adjusted, would the adjustments need to be electrically powered or could they be moved manually? (please check one choice in each

category in the table below)

Chair feature:	Manual adjust	Power adjust
Arm rests		
Leg rests		
Lateral supports		
Head support		
Control Mechanism		

7. Would it be important for you to be independent in performing this adjustment or could it be performed by an attendant? (please check one choice in each category in the table below)

Chair feature:	Chair user adjust	Attendant adjust
Arm rests		
Leg rests		
Lateral supports		
Head support		
Control Mechanism		

8. Please include any other comments regarding the design of a new seating system type below:

_____

APPENDIX B

DATA COLLECTION INSTRUMENTS USED FOR PHASE II RESEARCH

Phase 2 Instructions

Dear Research Subject,

Thank you for participating in the Wheelchair Seat Comfort study for the University of Pittsburgh. We appreciate your valuable input into this project. You are about to begin Phase 2 of this study. The purpose of this phase is to test the reliability and validity of a newly developed wheelchair seat discomfort assessment questionnaire.

You have been given a packet of information including the following:

Four copies of the questionnaire to complete – different colors
Four white envelopes (letter size)
One large brown envelope with a return address label and postage
Your copy of the consent form for participating in this study (please keep this)

For this research study, it is important that you follow these instructions carefully. You are being asked to do the following:

1) **Later today**, please complete the **YELLOW** colored questionnaire – this will be #1, note the date and the time that you completed this questionnaire. You may have completed this questionnaire with the researcher, if not, please place it into a white envelope and seal the envelope. Then please write the date and time on the white envelope.

2) One hour after you complete the **YELLOW** questionnaire, please complete the **BLUE** questionnaire and mark it #2. Note the time that you complete this questionnaire. Please place the **BLUE** questionnaire into a white envelope, seal it closed and write the date and time on the envelope.

3) **ONE WEEK LATER** please fill out the **PURPLE** questionnaire **at the same time of day** that you filled out the **YELLOW** questionnaire last week. This will also be marked #1. Please place this questionnaire into a white envelope and note the date and time of day you completed this questionnaire.

4) **ONE HOUR AFTER THE PURPLE** questionnaire, please complete the **GREEN** questionnaire. Mark this questionnaire #2. Place it into a white envelope and seal it in. Please note the date and time of day on the envelope.

5) Place **all FOUR** white envelopes into the brown envelope, seal it shut and place it in the US mail.

Thank you for your participation. If you have any questions, please do not hesitate to call me.

Barbara Crane
412-383-6583 – work number

Wheelchair Seating Discomfort Assessment Tool (WcS-DAT)

Introduction and directions:

This questionnaire has been developed as a way of determining the level of discomfort you are experiencing while you are sitting in your wheelchair.

There are three parts to this questionnaire:

- Part I asks you to provide general information that is important in evaluating seat discomfort.
- Part II asks you to rate your level of agreement with several statements that relate to comfort and discomfort.
- Part III asks you to assign a number on a scale from 0 to 10 to describe a discomfort level for each region of your body.

You are being asked to complete this questionnaire at 4-hour intervals once you are seated in your wheelchair. This means that you will complete the first questionnaire of the day 4 hours after you get into your chair in the morning, and then again every 4 hours after that. You will complete your final questionnaire before you get into bed at night, even if it has not been 4 hours since your last questionnaire.

Each time you complete a questionnaire, you should **only** consider the 4 hours you have just experienced – **not** the entire day. This means that each questionnaire will represent your feelings of discomfort over the preceding 4-hour period or since your last questionnaire (even if you did not spend the total 4 hours in your chair).

Part I: General Information:

1. What time did you first transfer into your wheelchair today? _____ am/pm

2. How much assistance do you need to transfer?

_____ I transfer completely by myself

_____ I require assistance from another person to help me transfer

_____ Another person transfers me, I am unable to help

_____ Another person uses a mechanical lifting device to transfer me

3. If someone assisted you in transferring, were you positioned properly in you chair after being transferred?

_____ yes _____ no

Describe problems if any occurred (anything out of the ordinary):

_____

4. What time is it now? _____ am/pm

5. In the last 4 hours, have you asked anyone to help you change your position in your wheelchair?

_____ yes _____ no

5a. If yes, how many times have you asked someone to reposition you? _____

6. In the last 4 hours, have you changed your own position?

_____ yes _____ no

6a. If yes, how many times have you changed your own position? _____

7. What types of activities have you done in your wheelchair in the last 4 hours?

(check all that apply)

_____ moved around in the house

_____ went outside of the house

_____ into the yard (grassy or rough surface)

_____ onto a deck or paved driveway

_____ traveled on a sidewalk surface

_____ traveled somewhere in a van or car

_____ went to work in my wheelchair

_____ went to school setting in my wheelchair

8. How many car lengths would you say you drove your wheelchair in the last 4 hours? _____
(a typical car is 12 feet long)

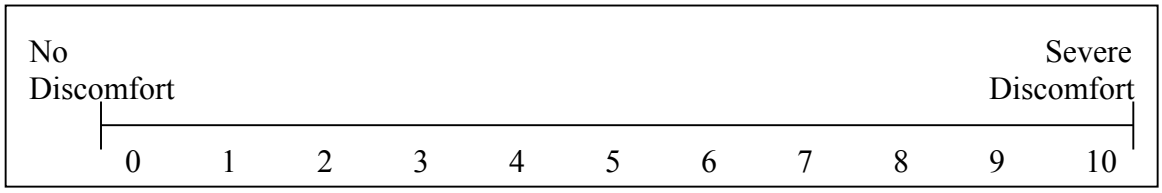
Wheelchair Seating Discomfort Assessment Tool (WCS-DAT)

Think about how you have felt while seated in your wheelchair during the last 4 hours:

Part II: General Discomfort Assessment

Please rate your answer on the following scale: (place a mark in the appropriate box)	Strongly disagree	Disagree	Partly disagree	Neither agree nor disagree	Partly agree	Agree	Strongly agree
While seated in my wheelchair…							
I feel poorly positioned							
I feel like I have been in one position for too long							
I feel like I need to move or shift my position							
I feel aches, stiffness, or soreness							
I feel pressure in some part or parts of my body							
I feel too hot or cold or damp							
I seek distraction to relieve discomfort							
I feel uncomfortable							
I feel no pain							
I feel stable (not sliding or falling)							
I feel comfortable							
I feel good							
I feel able to concentrate on my work or activities							

Part III: Discomfort Intensity Rating



Using this scale, please <u>RATE and DESCRIBE</u> the amount of discomfort you feel for each body area listed below. This rating should reflect the intensity of your discomfort <u>over the last 4-hour period, for the time you were in your wheelchair</u>:

Body Areas	<u>Rating:</u>	<u>Please describe</u> the discomfort (for example: aching, burning, pressure, instability, or others)
Back		
Neck		
Buttocks		
Legs		
Arms		
Feet		
Hands		
Other areas ? Please list:		
Overall Discomfort Level (General discomfort level)		

Is this an average day

On a scale of 0 to 10, with a 0 representing "the lowest amount of discomfort I have felt in the last 3 months" and a 10 representing the "highest amount of discomfort I have felt in the last 3 months," what number would best represent your general discomfort level today?

_____ (fill in number 0 to 10)

Using the same scale, what would represent an "average day" for you over the last 3 months?

_____ (fill in number 0 to 10)

APPENDIX C

DATA COLLECTION INSTRUMENTS USED FOR PHASE III RESEARCH

(printed on Department of Rehabilitation Science and Technology letterhead)

Dear Participant,

Thank you for helping us with the Dynamic Seating for Comfort wheelchair research study. We really appreciate your help with this important project and we hope you enjoy being involved in this study.

You are being provided with all of the necessary paperwork for participating in this study. We have tried to keep the paperwork to a minimum and have made every effort to provide forms that area easy to understand and require minimal time for completion. **However, we really need you to answer the questions at the proper times each day to insure that the date you provide can be used.**

You will receive one notebook for each week of participation. Each notebook contains 7 days of paperwork (in sections numbered from 1 to 7). I will be visiting you at least once per week and will provide you with the following week's notebook at this visit. I will also plan to contact you once per day by telephone to monitor your progress and answer any questions, **but this does not mean that you need to wait for my call if you have any questions.**

For **each day** you will complete the following forms:

- A daily log for recording your chair use pattern (white sheet)
- One seat discomfort assessment for **every 4-hours** that you sit as follows:
    - Complete after 4 hours of sitting (blue sheets)
    - Complete after 8 hours of sitting (gold sheets)
    - Complete if you sit between 8 and 12 hours (green sheets)*
    - Complete if you sit between 12 and 16 hours (grey sheets)*
    - Complete if you sit between 16 and 20 hours (light yellow sheets)*
- An assessment of how each day compares with your "average day" (pink sheet)
- A page for writing general comments or notes (pink sheet)
- A checklist of the day's paperwork to be sure you completed it all (pink sheet)

* These are optional – it depends on how long you sit each day

If you have any questions or problems while completing any of the paperwork, please do not hesitate to call me at my office or to page me. My office number is **412-383-6583** and my pager number is **1-800-217-5390**. I can always be reached at one of these two numbers!

Thank you,

Barbara Crane
Research Associate
University of Pittsburgh

Daily Log of Sitting Time					
Time	Please check off the place where you spent the majority of time for each time block:				
AM:	Bed	Toilet	Shower	Wheelchair	Other chair (please describe)
5:00 - 5:30					
5:30 - 6:00					
6:00 - 6:30					
6:30 - 7:00					
7:00 - 7:30					
7:30 - 8:00					
8:00 - 8:30					
8:30 - 9:00					
9:00 - 9:30					
9:30 - 10:00					
10:00 - 10:30					
10:30 - 11:00					
11:00 - 11:30					
11:30 - Noon					
PM:					
Noon - 12:30					
12:30 - 1:00					
1:00 - 1:30					
1:30 - 2:00					
2:00 - 2:30					
2:30 - 3:00					
3:00 - 3:30					
3:30 - 4:00					
4:00 - 4:30					
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7:30 - 8:00					
8:00 - 8:30					
8:30 - 9:00					
9:00 - 9:30					
9:30 - 10:00					
10:00 - 10:30					
10:30 - 11:00					
11:00 - 11:30					
11:30 - Midnight					

Assessment Number 1
Complete after 4 hours of sitting

Introduction and directions:

This questionnaire has been developed as a way of determining the level of discomfort you experience while you are sitting in your wheelchair.

There are three parts to this questionnaire:

- Part I asks you to provide general information that is important in evaluating seat discomfort.
- Part II asks you to rate your level of agreement with several statements about comfort and discomfort.
- Part III asks you to assign a number on a scale from 0 to 10 to describe a discomfort level for each region of your body.

You are being asked to complete this questionnaire at 4-hour intervals once you are seated in your wheelchair. This means that you will complete this first questionnaire of the day 4 hours after you get into your chair.

Each time you complete a questionnaire, you should answer the questions based on the 4 hours you have just experienced – **not** the entire day.

If you are getting out of your wheelchair and staying out the remainder of the day, please complete this assessment and then skip to the pink sheets at the end of this section.

(Assessment number 1 is included as an example, each assessment contained the appropriate number and directions depending on when it was scheduled to be completed)

Part I: General Information:

1. What time did you first transfer into your wheelchair today? _____ am/pm

2. How much assistance do you need to transfer?

_____ I transfer completely by myself

_____ I require assistance from another person to help me transfer

_____ Another person transfers me, I am unable to help

_____ Another person uses a mechanical lifting device to transfer me

3. If someone assisted you in transferring, were you positioned properly in you chair after being transferred?

_____ yes _____ no

Describe problems if any occurred (anything out of the ordinary):

_____

4. What time is it now? _____ am/pm

5. In the last 4 hours, have you asked anyone to help you change your position in your wheelchair?

_____ yes _____ no

5a. If yes, how many times have you asked someone to reposition you? _____

6. In the last 4 hours, have you changed your own position?

_____ yes _____ no

6a. If yes, how many times have you changed your own position? _____

7. What types of activities have you done in your wheelchair in the last 4 hours?

(check all that apply)

_____ moved around in the house

_____ went outside of the house

_____ into the yard (grassy or rough surface)

_____ onto a deck or paved driveway

_____ traveled on a sidewalk surface

_____ traveled somewhere in a van or car

_____ went to work in my wheelchair

_____ went to school setting in my wheelchair

8. How many car lengths would you say you drove your wheelchair in the last 4 hours?

_____

(a typical car is 12 feet long)

Wheelchair Seating Discomfort Assessment Tool (WCS-DAT)

Think about how you have felt while seated in your wheelchair during the last 4 hours:

Part II: General Discomfort Assessment

Please rate your answer on the following scale: (place a mark in the appropriate box)	Strongly disagree	Disagree	Partly disagree	Neither agree nor disagree	Partly agree	Agree	Strongly agree
While seated in my wheelchair…							
…I feel poorly positioned							
…I feel like I have been in one position for too long							
…I feel like I need to move or shift my position							
…I feel aches, stiffness, or soreness							
…I feel pressure in some part or parts of my body							
…I feel too hot or cold or damp							
…I seek distraction to relieve discomfort							
…I feel uncomfortable							
…I feel no pain							
…I feel stable (not sliding or falling)							
…I feel comfortable							
…I feel good							
…I feel able to concentrate on my work or activities							

Part III: Discomfort Intensity Rating

On a scale of 0 to 10, **0 being no discomfort** and **10 being severe discomfort**, please **RATE and DESCRIBE** the amount of discomfort you feel for each body area listed below.

This rating should reflect the intensity of your discomfort over the last 4-hour period, for the time you were in your wheelchair:

Body Areas	Rating:	Please describe the discomfort (for example: aching, burning, pressure, instability, or others)
Back		
Neck		
Buttocks		
Legs		
Arms		
Feet		
Hands		
Overall Discomfort Level (General discomfort level)		
Other areas? Please list:		

Is this an average day?

On a scale of 0 to 10, where:
0 = "the lowest amount of discomfort I have felt in the last 3 months"; and
10 = "the highest amount of discomfort I have felt in the last 3 months"

1. What number would best represent your general discomfort level **today**?

_____ (fill in number 0 to 10)

2. What number would represent an "**average day**" for you during the last 3 months?

_____ (fill in number 0 to 10)

Please review and answer the following questions based on your use of the PTS2 test wheelchair today:

1. Do you have any **new** reddened areas of skin on your buttocks or posterior thighs?

Yes ____*
No ____

*If yes, call Barbara Crane at 412-383-6583 or page her at 1-800-217-5390 and discontinue use of the PTS2 wheelchair

2. Did you experience any difficulties in using the PTS2 wheelchair or seat controls today?

Yes ____*
No ____

*If yes, call Barbara Crane at 412-383-6583 or page her at 1-800-217-5390 and describe the problem below:

_____
_____
_____
_____

PTS2 WHEELCHAIR USERS GUIDE

Introduction

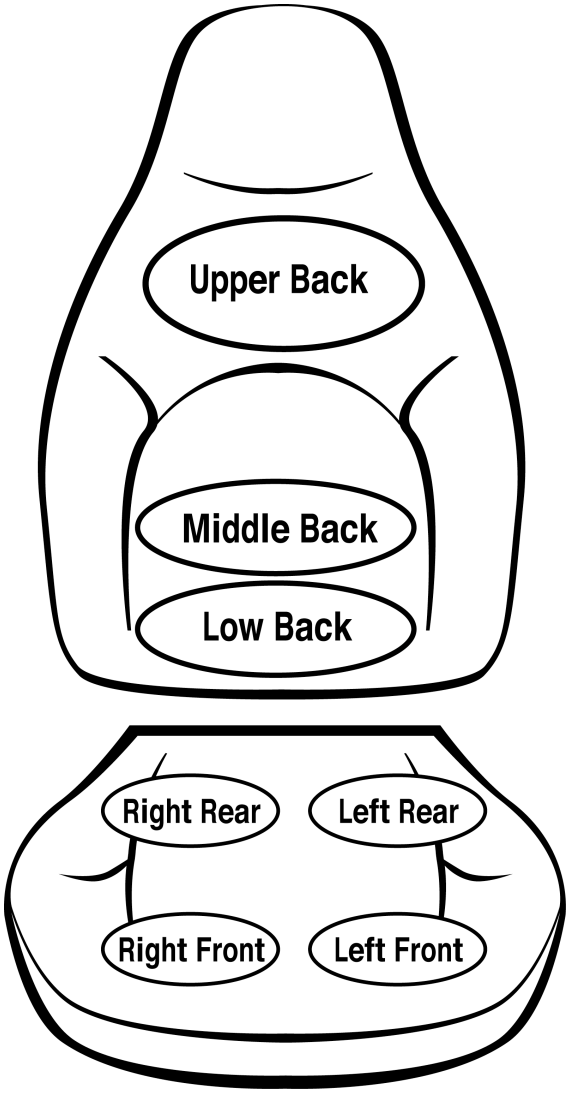
The PTS2 wheelchair is a specialized wheelchair developed to evaluate a dynamic seat for relieving sitting discomfort. It was developed for the research study titled "Investigation of Dynamic Seating for Comfort."

The chair uses technology from the wheelchair and automotive industries. It is comprised of a Permobil Chairman power wheelchair base with power tilt, power recline, power elevating leg rests, and power seat lift functions. Mounted to the Permobil seat frame is an automobile seat system that has been customized for this study. Four air bladders have been inserted inside the seat cushion, and three air bladders have been inserted inside the back cushion.

The chair has two control interface devices – one for driving the wheelchair (joystick) and one for operating the seat functions. Both control interfaces are connected to an instrumentation system that controls the operation of the chair and monitors the usage of each of the features. The chair runs on battery power supplied by two12-volt wheelchair batteries.

The Seat and Back Cushions:

The seat cushion and back cushion of this chair each contain special air bladders that make it possible to change the firmness of the cushions in different regions of your body. This will allow you to adjust the pressure points exerted by the seat and back, and may help you in making small postural adjustments or shifts. The inflation level of the seat and back bladders is adjusted by pressing the corresponding buttons on the control panel (see next section on control panel).

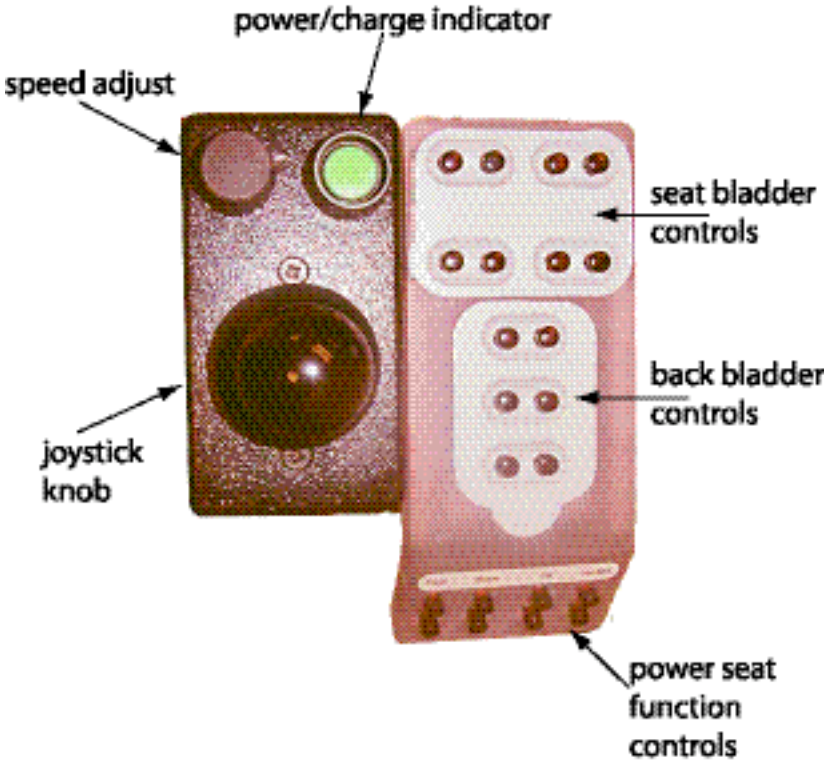


This diagram indicates the approximate locations of each of the bladders.

Control Panels:

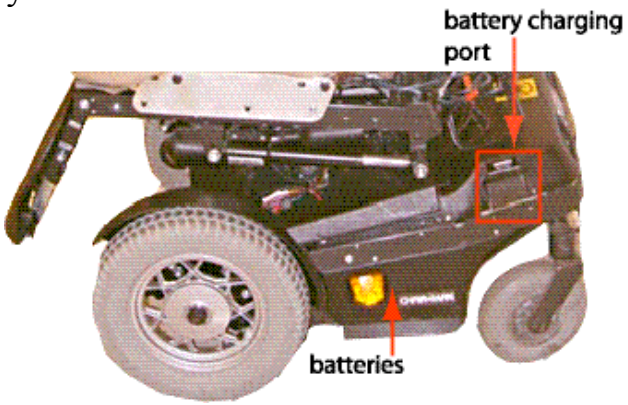
There are two control panels for this chair. In the picture below, the panel on the left operates the wheelchair driving functions. The green button turns the power for the chair on and off, the round dial to the left of the green button allows you to adjust the maximum speed of the chair, and the larger knob below these is the joystick drive control.

The panel on the right operates the inflation and deflation of the individual air bladders and the wheelchair power seat functions. The top section of the control panel represents the wheelchair seat cushion. Each pair of buttons – inflates and deflates the corresponding air bladder inside the seat cushion. The mid section of the control panel represents the wheelchair back cushion and contains three pair of buttons, these inflate and deflate the air bladders in the back cushion of the chair. At the bottom of the panel is the section that contains all of the power seat functions – these are labeled for ease of use.



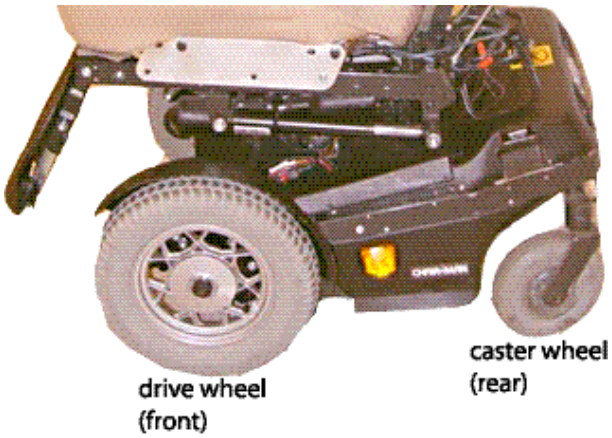
Batteries and Charging

The wheelchair is powered by a pair of normal 12-volt wheelchair batteries. The batteries are located underneath the seat, inside the black protective case of the wheelchair base. There is a charging port on the left hand side of the chair, just behind the seat. The batteries for this chair should be charged every night, even if you do not normally charge your own wheelchair every night. This is necessary because this chair uses more power in order to operate all of the special features. The wheelchair should run all day on a full charge. However, if you notice the green light blinking when the chair is turned on, you may need to charge it soon. This blinking green light indicates a low battery level.



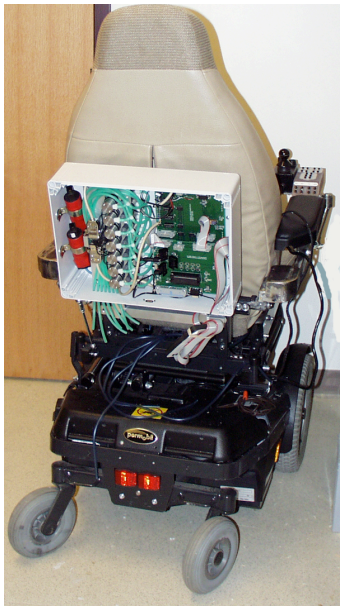
Wheels and Tires

The wheelchair has two larger drive wheels in the front. These wheels contain air-filled tire tubes. If the air in these tires appears to be low, or if one of these tires develops a flat tire, please call the researchers at the number provided. The chair also has two smaller wheels in the rear of the chair – these are called casters.



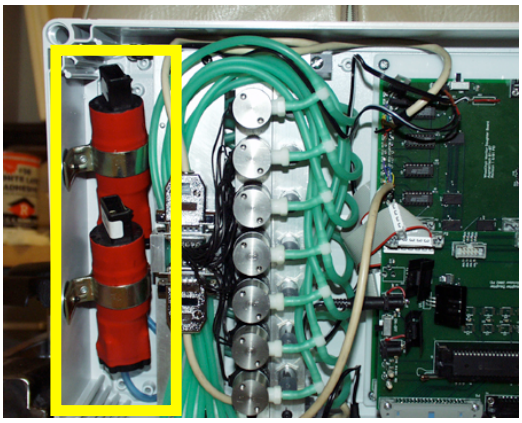
Special equipment

The wheelchair is also equipped with additional instrumentation required to operate the extra functions and to monitor the usage of the chair. All of this special equipment is located in a box mounted on the back of the chair. Please do not touch this instrumentation. If you think there is a problem with it, please contact the research team.



Air bladder inflation pumps

The seat's air bladders, operated with the buttons on your control panel, are inflated using small air pumps attached to the bladders by small tubes. These pumps are contained inside the box mounted to the back of the chair (in the picture below they are the red items inside the yellow box). These pumps make a small amount of noise when they are pumping air into the bladders. This is normal. If you think that the pumps are not working properly or if you stop hearing noise when you try to inflate the bladders, please contact the research team.



Protecting the chair from moisture

The control panels and the electronic equipment mounted behind the chair should be protected from bad weather to the greatest extent possible. While many normal wheelchair components are sealed for added protection from moisture, this chair contains features that do not have this added protection. If you need to go outside in very wet or rainy weather, please use your personal wheelchair rather than this test wheelchair. Please try to avoid spilling liquids on the control panel that operates the air bladders. If the controls are exposed to liquid, they may no longer work properly – that is, when you push buttons, the bladders or seat functions may fail to operate. If this occurs, please contact the researcher team.

Research Team Contact Information

Barbara Crane is the research coordinator for this project. Please contact her directly if there are any problems with the wheelchair or if you have any questions about the chair or the research documents.

Pager Number and Directions: Dial: **1-800-217-5390** – enter **your** phone number at the prompt, then wait for it to confirm that the message will be sent **before hanging up**.

Work Phone: **412-383-6583**

Email: bacst62@pitt.edu or cranebar@cs.com

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