

Impact of wheelchair type on reducing the risk of shoulder overuse injuries following spinal cord injury

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I, Lone Skriver Rose, confirm that the work presented is my own. Where information has been derived from other sources, I confirm that this has been indicated in my thesis.

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ABSTRACT

With the extensive support of the UK spinal cord injuries centres (SCIC) two surveys were conducted to evaluate changes in wheelchair provision to people with spinal cord injury (SCI) before and after the introduction of the Wheelchair Voucher Scheme in 1997. The surveys covered the periods 1991-1997 and 1998-2004.

Of the 526 manual wheelchair users recruited from the eight SCICs in England for the 1991-1997 survey, 52% abandoned their initial wheelchair within one year of discharge. The main reason for changing the wheelchair was 'pushability', i.e. the effort involved in propulsion. As there is a period of adaptation and consolidation of skills following discharge back into the community, a pilot biomechanical study was designed to investigate further whether this change of wheelchair was triggered by changes in the propulsion biomechanics over time or due to other changes in the participants. The pilot study examined a cohort of 19 newly injured people at time of discharge, 13 of whom were retested at six months post-discharge.

There is a growing body of evidence linking the use of a manual wheelchair to secondary upper limb problems. No previous studies have analysed the severity of shoulder pain and associated it with the types of wheelchairs used. The participants in the wheelchair provision survey were invited to complete the Wheelchair User's Shoulder Pain Index (WUSPI) to evaluate the size of the problem in this population and relate it to their specific wheelchair use. This study group comprised 705 full-time manual wheelchair users, recruited from 10 SCICs throughout the UK.

The comparison of the 1991-97 and 1998-2004 surveys showed that wheelchair provision has changed towards the lighter and more customizable wheelchair. Some significant changes in propulsion biomechanics were found between the results at discharge and six months. The shoulder pain analysis revealed that pain was reported to be more severe in individuals using folding frame manual wheelchairs.

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1. INTRODUCTION

Until the 1980s, the standard issue wheelchair commonly weighed 40 lbs (18.2 kg) or more. However, the 1980s saw the introduction of a new generation of wheelchairs commonly referred to as lightweight or ultralight wheelchairs. 'Ultralight' was defined by Cooper *et al.* (1996) as weighing less than 25 lbs (11.4 kg). The revolution in wheelchair design during the 1980s saw the lightweight manual wheelchair evolve from a predominantly sporty wheelchair into one for everyday usage. Not only was the design lighter and more modern; the wheelchair could also be adjusted much more to the user in terms of size, backrest height and seat/backrest angle. The reduction in weight was due to the use of new materials and this feature soon came to dominate the new terminology surrounding this new generation of wheelchairs. However, the focus on the weight of this new style of wheelchair somewhat detracted from the biggest advance in the design, which was the invention of the detachable rear wheel with an adjustable rear-axle plate. This feature made it possible to adjust the position of the rear wheel axle in relation to the user within the wheelchair. This gave rise to the term 'high performance' wheelchair which more accurately reflected the benefit of this new design to the user¹: a cosmetically more pleasing wheelchair which could be propelled with far less effort. For the clinician this evolving change in wheelchair design meant access to a wider selection of wheelchairs with a 'pick and mix' range of features. No longer did the user have to fit the chair; it was now possible to prescribe a wheelchair to suit the individual both in terms of posture and functional ability.

This dramatic change in wheelchair design was taking place against the background of a simultaneous shift in the work being carried out on establishing international standards for wheelchair prescription. Work on this had previously concentrated on the durability, ease of maintenance and cost of prescribed

¹ The term 'patient', 'user' and 'individual' are used interchangeably throughout text depending on the context.

wheelchairs. Although more costly, the new style of wheelchair proved to be more durable than the standard wheelchairs (Cooper et al. 1996; Cooper et al. 1997a). This is of particular relevance to the more active user, where wear and tear associated with going up and down a kerb would be an everyday occurrence. The ability to adjust the position of the rear wheel axle in a forward direction made it a lot easier to lift the front castors and balance on the rear wheels ('wheelie'), an essential skill in negotiating kerbs independently. This also made the wheelchair potentially more unstable in a rearward direction so the adjustment of the rear wheel position had to be matched carefully to the user's skill to control the wheelchair. The international standards being developed started to reflect the need for ways of characterising stability issues and the functional benefits to the user. The change in design from the traditional cross frame ('folding') design to a box frame ('rigid') design informed changes in clinical practice as well, particularly in relation to transfers and methods of loading the wheelchair into a car.

The demand for this style of wheelchair grew very rapidly, spearheaded by the more active user groups, in particular the spinal cord injured population. However, at the time of this sea change in wheelchair design the Wheelchair Services in the UK could only provide wheelchairs from a list approved by the Department of Health and Social Security (DHSS). It was not until the devolution of these services in 1991 from regional to district level that each wheelchair service could decide whether or not to include this new generation of wheelchairs in the range of equipment provided. The spinal cord injury centres (SCICs) were well placed to monitor if this was happening. Clinical experience from the Seating Clinic at the National Spinal Injuries Centre (NSIC) indicated that most new-generation wheelchairs were purchased privately. However, there was no independent evidence to support this experience.

With the announcement that a Wheelchair Voucher Scheme would be introduced during 1997-1998, the SCICs in England agreed to carry out a national survey covering the period 1991-1997 period to establish a baseline of provision to people with spinal cord injury (SCI) before this came into effect. As the Wheelchair Voucher Scheme gave the user the option of contributing

financially to the purchase of a wheelchair, this change had the potential to dramatically influence the types of wheelchairs being used. To be able to make a 'before and after' comparison, a follow-up survey covering the 1998-2004 period was also carried out. This forms the first part of this thesis.

One of the findings from the 1991-1997 survey (Rose et al. 2002a) was that 52% of the users in England abandoned the wheelchair they had been provided with on discharge within the first year of discharge in favour of a lighter and more customizable wheelchair. The main reason given for this change of wheelchair was 'pushability', i.e. the effort required to propel the wheelchair. Although the people most likely to abandon their wheelchair early were those who had been issued with a more basic style of wheelchair, this was not exclusively so (Rose et al. 2002b). One possible explanation for why some users with a customizable wheelchair also chose to abandon it within the first year, could be that they simply were not aware of the full scope for adjustment of their wheelchair. A continued improvement in strength, balance and especially in confidence following discharge might also influence a user's view of what they want from their wheelchair. The anecdotal impression from clinical practice was that there follows a period of both emotional and physical adjustment after discharge from the SCIC. The effect of this adjustment will be particularly evident in tasks like transfers and advanced wheelchair skills such as going up and down kerbs and negotiating uneven ground. This change in physical ability and emotional adjustment may have played a part in the level of abandonment as well. The data from the survey was not able to pinpoint whether the high level of abandonment was due to changes in the needs of the individual, lack of knowledge regarding ongoing adjustment of the wheelchair or whether the initial configuration² and type of wheelchair was unsuitable from the outset. It was this need to more fully understand the circumstances that may influence wheelchair use in the early stages following discharge that informed the design of a pilot biomechanical study. The objective of the pilot study was to investigate changes in propulsion biomechanics in a group of individuals during

² 'Configuration' and 'set-up' is used throughout the text to describe the way the wheelchair had been adjusted.

the first year post-discharge in an attempt to identify which parameters would be most useful to use in a future, larger study. This pilot study forms the second part of this thesis.

As life expectancy following SCI is increasing, people with SCI may now spend 50+ years as manual wheelchair users. This exposes them not only to the usual problems associated with ageing but also to problems of overuse injuries to the upper limb; these commonly manifest themselves as carpal tunnel syndrome (CTS) and rotator cuff tears. In the last decade many studies have investigated propulsion biomechanics in the manual wheelchair user. There is a growing body of evidence linking manual wheelchair use to these overuse injuries (Alm et al. 2008;Boninger et al. 1999;Boninger et al. 2002;Boninger et al. 2005;Brubaker 1986;Curtis et al. 1999a). Most of these studies have been carried out outside the UK and none has linked the prevalence of shoulder pain to the specific type of manual wheelchair used. The 1998-2004 survey described in this thesis offered an opportunity to establish the prevalence of this problem in a SCI population resident in the UK and analyse it against specific wheelchair type.

The participants in the 1998-2004 survey were invited to complete the Wheelchair User's Shoulder Pain Index (WUSPI) and the data from this informs the final aspect of this thesis.

2. LITERATURE REVIEW

This thesis should be seen in the context of the changes to the Wheelchair Service delivery system in the United Kingdom since 1991, which coincided with the dramatic international development in new wheelchair design. The basic characteristics of SCI and the role of the SCICs are explained in Section 2.1. Section 2.2 describes the Wheelchair Service delivery system prior to and during this study. It comments on the reports which have been commissioned to assess the success of the changes to the Wheelchair Service delivery system. The development of a new generation of wheelchairs is outlined in Section 2.3. The Wheelchair Voucher Scheme is explained in Section 2.4. The work investigating propulsion biomechanics is discussed in Section 2.5 with an introduction to the SmartWheel, which was used in the propulsion biomechanics study in this research. Finally, in Section 2.6, the literature pertaining to manual wheelchair propulsion and shoulder pain is presented and put into the context of this thesis. The research objectives for this thesis are defined in Section 2.7.

2.1 Characteristics of spinal cord injury

People with a SCI constitute an ideal population for the purpose of this thesis. First, they are easily identifiable via the SCICs. Second, they represent a fairly uniform user-group in terms of wheelchair needs and predicted functional outcomes (Bergstrom et al. 1992). Third, as a user-group, they place particularly high demands on their wheelchair and Wheelchair Service. They are typically younger people who were fit and healthy before sustaining their SCI and have the potential to live full and active lives. They have very high expectations of how the wheelchair will enable them to return to their chosen level of social integration and participation following discharge.

There are eight SCICs in England with further regional centres in Scotland, Wales and Northern Ireland. These rehabilitation centres are dedicated to a multi-disciplinary approach to rehabilitating an individual with SCI from injury onset to completion of rehabilitation and beyond. Most of the SCICs offer lifelong follow-up care.

The absence of national reporting makes it difficult to establish exact prevalence and incidence figures for SCI. Furthermore, not all individuals with a SCI will be referred to a specialist centre. Data collected from the SCICs in the United Kingdom suggest that traumatic SCI (TSCI) affects around 40,000 people in the UK (MASCIP et al. 2008). It is estimated that there are 700 – 1,000 new cases / year. According to the Annual Report of the Spinal Injuries Association (SIA) 2008 - 2009, the majority of people who sustain a SCI are active, male and between 21 and 30 years old. SCI is caused by either *traumatic* injuries (70%), e.g. road traffic accidents (27%), falls (26%) or sports injuries (13%), or *non-traumatic* injuries (30%), which are primarily vascular or due to tumour or infection (Spinal Injuries Association 2009).

For the purpose of this study no distinction was made between traumatic or non-traumatic cause.

Regardless of cause, SCI results in loss of power, sensation and autonomic function below the level of the lesion, which combine to have implications not only for function but also for posture and tissue integrity. SCI is classified according to the level of the lesion. If the lesion is in the cervical segment of the spinal cord (C1-8), upper limb function as well as trunk and lower limb function will be affected (tetraplegia). Where the lesion is in the thoracic, lumbar or sacral segments (T1-12, L1-5, S1-5) the SCI will be classified as 'paraplegia' (ASIA 2011). For the individual with a thoracic lesion, there will be full use of the upper limbs with paralysis of the lower limbs and some compromise of trunk balance depending on the degree of trunk involvement. In lumbar and sacral lesions, there will be full use of upper limbs and trunk and either complete paralysis or some residual function in the lower limbs. The activity preserved in the lower limbs is not necessarily sufficient for functional ambulation and a wheelchair would usually be required for long distances.

The life expectancy for people with SCI will depend on level of and age at injury. Although shorter than for the general population, it continues to increase (Frankel et al. 1998). As SCI is usually a stable, non-progressive condition, the level of functional ability can be expected to continue to improve after discharge due to increased strength, balance and confidence. In order to achieve and

maintain his or her maximum potential, the spinal cord injured individual is currently totally dependent on a wheelchair, which will thus be required, not only to enable, but also to be active in facilitating the highest level of independence, participation and social integration (World Health Organisation 2002). 'Being independent' is open to interpretation, but from a wheelchair skills point of view, this would generally depend on the ability to at least flick the front castors of the wheelchair to negotiate small thresholds or kerbs and at best be able to control the wheelchair whilst balancing on the rear wheels ('wheelie'). The ability to back-wheel balance (bwb) is required to go up and down larger kerbs, go over rough ground and, for the most confident and strong users, enable them to negotiate stairs with minimal or no assistance. For any individual with the ability to transfer in and out of a car, being able to load the wheelchair independently into the car would be considered an integral part of this skill. These skills are typical goals in the spinal cord injured population but rarer in other disability groups. However, the type of wheelchair used will have a great impact on how easily these skills can be achieved and maintained.

2.2 Wheelchair Service delivery system in the United Kingdom

The publication of the McColl report (McColl I 1986) prompted the devolution of the Wheelchair Services in the UK from regional to district level with effect from January 1, 1991. Prior to this, wheelchairs were provided according to the 'Handbook of Wheel Chairs and Hand Propelled Tricycles', a list of equipment approved by the Department of Health and Social Services (DHSS). The statutory requirements of the Wheelchair Services were enshrined in the National Health Service Act of 1977 (NHSA) (Department of Health 2006). Sections 2 and 3 of this Act state that there is a duty to meet all reasonable requirements and provide facilities or services for the diagnosis and treatment of illness. In this context, any disability requiring medical or nursing treatment would be considered part of 'illness' and a wheelchair would be considered a 'facility or service'.

It is estimated that there are 1.2 million wheelchair users in England (emPower 2004). Of these 825,000 are thought to be regular users. The Wheelchair

Services³ provide for all types of mobility impairment; the spinal cord injured population only constitutes a very small percentage (1.3%) of all wheelchair users (Lachmann S et al. 1995).

Following the devolution of services in 1991, each Wheelchair Service was given budgetary control and hence greater autonomy in deciding what range of wheelchairs could be provided by that service. Crucially there were no agreed national standards or guidelines to best practice at this time. This gave rise to growing inequality in service provision and dissatisfaction amongst service users with the assessment and prescription of wheelchairs. Service users were also beginning to express concern that the wheelchairs being provided were too heavy (Prosthetic and Wheelchair Committee 1996).

Subsequent to the devolution of services, several initiatives have investigated the equality and efficiency of the Wheelchair Services, resulting in a flurry of reports over the last decade. Some of these are discussed in the following section.

The Audit Commission report 'Fully Equipped' (Audit Commission 2000) highlighted serious shortcomings in the provision of wheelchairs by the National Health Service (NHS). It suggested that the quality of equipment supplied on the NHS was not always reasonable and tended to support dependence rather than restore autonomy. It stressed that proper equipment is central to effective rehabilitation and commented that if services do not meet the needs of the user first time, poor clinical outcomes are likely, compounding the waste of public money. The report also reflected large geographic variations in the equipment provided by the Wheelchair Services, the so-called 'postcode lottery'. A follow-up report (Audit Commission 2002) concluded that very little of the new money provided for the re-structuring of equipment services had been spent in accordance with the original intention of improving equipment services and stated that progress had been patchy.

³ Throughout the text the term 'Wheelchair Service' refers to the service which is part of the National Health Service (NHS) and provides wheelchairs to anybody entitled to NHS provision.

Following the 'Fully Equipped' reports, the Department of Health in collaboration with the Audit Commission and the Modernisation Agency launched the Wheelchair Services Collaborative in November 2002. Forty-five out of the 151 Wheelchair Services in England were selected to take part in this initiative which aimed to identify areas for improvement in service provision and improve efficiency. Although there was no additional funding available and any improvements identified had to be achieved within existing funding, it is generally felt to have been a constructive exercise and has led to the publication of a Good Practice Guide (NHS Modernisation Agency 2004). The purpose of this document is to give guidance to Wheelchair Services on how best to identify, evaluate and develop a strategy for improvement in areas of the service such as setting eligibility criteria, dealing with inappropriate referrals, reducing waiting times from referral to first assessment, and minimising delays in ordering and delivery of equipment.

A more recent review of wheelchair provision in England is published in the 'Out and About' report (Care Services Improvement Partnership 2006). It acknowledges in its introduction that "without change and investment, Wheelchair Services will not be able to meet the expectations of users or the current health and social care agendas" and that "wheelchair provision affects quality of life, health and well-being and is important in facilitating social inclusion and improving life chances" (p 2). This reflects more closely the three pillars of the International Classification of Functioning, Disability and Health (ICF): impairment, activity and participation (World Health Organisation 2002). Through case scenarios the 'Out and About' report demonstrates how providing a wheelchair, which may be more expensive initially to purchase, can result in immediate and significant savings for other areas of the Health Service by preventing secondary health problems, e.g. tissue breakdown, respiratory and urinary infections. The report highlights how, when faced with budgetary pressures, the long-term and wider benefits of providing an appropriate wheelchair are often lost for the benefit of securing short-term financial savings. This has driven some services to operate a ceiling on the amount they will spend on any one chair (p 10). It includes a range of non-mandatory recommendations regarding the assessment process and service organisation.

Appendix 2 of the report contains a list of best practice standards, which it suggests could provide “opportunities for national benchmarking” (p 6).

A separate review of the wheelchair and seating services for Scotland also commented on the need to consider the wider health benefits of providing appropriate seating. A simple example is the potential for a reduction in the use of painkillers or anti-spasticity medication when an individual is seated correctly and comfortably. Amongst the recommendations it suggests using Quality-Adjusted Life-Years (QALY) to account specifically for the associated benefits of appropriate provision, not just to the individual but to the health service as a whole (Scottish Executive 2006).

In spite of this wealth of advice and guidance on how to improve service delivery and the recognition that there are new technologies which service users want to be able to access, there has been no detectable increase in the budgets intended for the provision of wheelchairs since the additional funding allocated in 1996 for the introduction of the EPIOC⁴ and Voucher Schemes (Care Services Improvement Partnership 2006). All these reports measure improvement in terms of meeting the targets set for time from referral to assessment, from assessment to equipment order and from order to delivery of equipment to the Wheelchair Service in preparation for handover to the user. None addresses the issue of how well the needs of the clients are being met in terms of providing the types of wheelchairs that the users feel they need.

2.3 Changes in wheelchair design

The changes highlighted in [Chapter 2.2](#) to the service delivery system in the UK took place against a background of great changes in the design and development of manual wheelchairs. The rigid frame style of wheelchair, first seen in the sports wheelchairs, soon found its way into mainstream use (Cooper 1991). The use of different materials, such as aluminium and titanium, greatly reduced the overall weight of the wheelchair. This was particularly evident in the rigid frame wheelchair, but also applied to the traditional folding,

⁴ EPIOC: Electrically Powered Indoor/Outdoor Wheelchairs.

cross-frame style of wheelchair. An example of a rigid and a folding frame style of wheelchair are given in Figure 1.



Figure 1 Rigid frame wheelchair ([Quickie GPV](#)) and folding cross-frame wheelchair ([Etac Cross](#))

The introduction of the detachable rear wheel with an adjustable axle-plate enabled adjustments to be made to the rear wheel position in relation to the seat, thus affecting the distribution of weight between front and rear wheels as well as the seat height in relation to the wheels. Moving the rear axle forward has the effect of off-loading the front castors and hence reducing the rolling resistance (Brubaker 1986). Combined with a reduction in overall weight of the wheelchair, this has the effect of enabling the user to propel faster and travel further with reduced energy expenditure (Beekman et al. 1999). The downside to a more forward rear axle position is increased rearward instability (Majaess et al. 1993). Hence, in order to prescribe appropriately, additional training of clinicians is required to ensure a robust understanding of the implications of wheelchair set-up on function and stability. As the set-up of the wheelchair needs to be carefully matched to the user's ability to control and use the wheelchair safely within their own environment, access to adequate wheelchair skills training is of utmost importance to the user (Hills 2010).

The additional ability to adjust the backrest height and, in some wheelchairs, the angle and tension of the backrest according to the individual's stature and ability to balance, combined to improve user posture and comfort. With the advances in design, the needs of the user could be met with much more appropriate wheelchair prescription. As suggested by Brubaker *et al.* (1986) the question was no longer having to provide justification for prescribing a new generation

wheelchair, but rather that the clinician should be required to provide justification for prescribing a standard wheelchair.

Nowhere was the growing discrepancy in provision more evident than in the SCICs. As the centres tend to cover large geographical areas, each centre has patients from within the catchment areas of a range of Wheelchair Services. The largest SCIC in the UK is the National Spinal Injuries Centre (NSIC) at Stoke Mandeville Hospital with more than 100 beds. The experience from the Seating Clinic at the NSIC is that at any one time it may be dealing with as many as 60 Wheelchair Services, each with different eligibility and provision criteria. Consequently, two patients with the same level of clinical need could be provided with completely different types of wheelchairs. Solid evidence to support clinical recommendations for provision of wheelchairs which more closely matched the needs of the user was required.

The systematic review of research in this field published by the Consortium of Spinal Cord Medicine provided some evidence (Consortium for Spinal Cord Medicine 2005). In recommendation 7, p13, it states that users with a SCI should be provided with “a high-strength, fully customizable manual wheelchair made of the lightest possible material”. The reasons given in support of this recommendation are that a lighter wheelchair requires less force for propulsion (Beekman et al. 1999), a lighter wheelchair design has the facility to move the rear wheel axle forward in order to reduce the rolling resistance and can be adjusted to fit the user (Brubaker 1986), and lighter wheelchairs are made with better components and cost less to operate. Cooper *et al.* (1996; 1997a) carried out tests on standard (weight > 16 kg), lightweight (weight 11.4 – 16 kg) and ultralight (weight < 11.4 kg) wheelchairs against internationally accepted fatigue standards. They found that the ultralight wheelchair lasted 13.2 times longer than the standard and 4.8 times longer than the lightweight wheelchairs. The ultralight wheelchair also costs 3.5 times less to operate than the standard and 2.3 times less than the lightweight wheelchairs. When tested to failure, the ultralight wheelchair was found to last the longest and have fewer catastrophic failures (Fitzgerald et al. 2001). Not only does this new generation of wheelchair offer great advantages to the user. They are also more cost-effective in the

long-term due to greater durability and less risk of premature failure and possible risk to the user.

Spearheaded by the more active and independent users, such as the spinal cord injured population, the demand for this new generation of wheelchairs to be made available on the NHS grew quickly. As the new generation of wheelchairs was considerably more expensive to purchase than the standard NHS wheelchair, it was difficult to meet this demand within existing budgets. Despite the growing body of evidence supporting the functional and clinical benefits and proving the increased value for money associated with improved durability that the provision of these wheelchairs can offer, funding remained an issue. After a period of lobbying by user groups and consultation with professional groups, the idea of a wheelchair voucher scheme was conceived.

2.4 Wheelchair Voucher Scheme

The introduction of the Voucher Scheme (NHS Executive & Department of Health 2000) was seen by many clinicians as an opportunity to change and improve wheelchair provision by giving users the option to contribute financially towards a wheelchair of their choice and become more involved in the decision making process. The Voucher Scheme gives the user three options: from the range offered by the Wheelchair Service, the user could accept outright the wheelchair, which was deemed to be meeting his/her clinical needs at the time. Alternatively the user could accept a voucher to the value of the NHS wheelchair offered and use that towards the purchase of a wheelchair through either partnership or independent options. In effect, the intention of the voucher was to enable the user to upgrade to their choice of wheelchair. On the partnership option the user can choose a wheelchair from an extended but still limited range of wheelchairs supplied by the Wheelchair Service; the wheelchair remains the property of the Wheelchair Service and continues to be maintained by the service. On the independent option the user can choose from the full range of wheelchairs available through approved dealers; the wheelchair becomes the property and responsibility of the user. The Wheelchair Service has to be satisfied that the wheelchair chosen is suitable for the needs of the user before releasing the voucher to the dealer.

At the time of the implementation of the Voucher Scheme, a voucher would not usually be renewed within a five-year period. In effect, the user could not go back to the Wheelchair Service to change the wheelchair if it turned out to be sub-optimal. Only if there had been a significant change in clinical need would the Wheelchair Service consider providing another wheelchair or renewing the voucher. This condition has since been changed in some areas to a three year interval. Based on the findings from the 1991-1997 survey (more than half the respondents changed their wheelchair within one year of discharge) it does not seem to be in the best interest of a first-time wheelchair user to opt for a voucher for the first long-term wheelchair. Current practice in SCIC is to advise against using a voucher for the first long-term wheelchair.

As the main reason for changing the wheelchair early was linked to the ability to propel the wheelchair (Rose et al. 2002b) a pilot study to investigate further the changes in propulsion biomechanics in the first year post discharge was designed.

2.5 Propulsion biomechanics

The ability of the individual to propel the wheelchair is influenced by the user, e.g. body dimensions and degree of impairment, by the wheelchair and by the interface between the two, i.e. the fit and set-up of the wheelchair in relation to the user. This requires consideration of the processes involved in manual wheelchair propulsion.

Manual wheelchair propulsion consists of two phases: the push phase and the recovery phase. To initiate the push phase the user grips either the tyre of the rear wheel or the pushrim (Figure 2). Some users prefer to grip both, especially when maximum effort is required such as when going up a kerb or pushing up a steep incline. The end of the push phase and the start of the recovery phase is when the wheel is released at the end of the push.

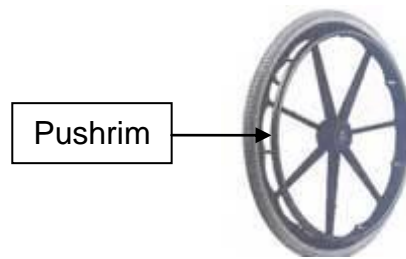


Figure 2 Example of rear wheel with pushrim.

The development of the SmartWheel ([Three Rivers Holdings](#)) enabled researchers to study in more detail the individual forces involved in manual pushrim propulsion. This instrumented pushrim was originally intended to improve understanding and performance in wheelchair racing (Cooper 2009). Following the discovery by Boninger *et al.* (1996) that wheelchair athletes did not seem to be at higher risk of sustaining repetitive strain injuries to the upper limbs, the focus of study gradually shifted towards manual wheelchair users generally and wheelchair configuration in particular. The instrumentation in the SmartWheel allows the researcher to analyse the forces involved in propulsion from the moment the hand touches the pushrim to the moment it is released. It also records stroke frequency, stroke length (the arc formed while the hand is in contact with the rim) and calculates the velocity of propulsion (Figure 3).



Figure 3. The SmartWheel mounted on wheelchair ([Three Rivers Holdings](#)).

An important aspect of the SmartWheel as an assessment tool is that it can be mounted to most wheelchairs with a detachable rear wheel, thus enabling study of the user in their own wheelchair. Due to the instrumentation, the SmartWheel weighs 4.9kg and is heavier than the wheel it substitutes, thus adding to the

overall weight of the wheelchair. Unless a SmartWheel is mounted on both sides of the wheelchair or the opposite wheel is counter weighted, it has the potential to influence the balance and weight distribution of the wheelchair.

Multiple studies of propulsion biomechanics have concluded that the adjustment of the rear wheel in the vertical and the horizontal plane in relation to the user has a significant impact on upper extremity forces during propulsion (Boninger et al. 2000; Kotajarvi et al. 2004; van der Woude et al. 1989). Study of propulsion patterns helped to define the characteristics of the most commonly seen patterns and identify the most effective (Boninger et al. 2002). The recommendation from The Clinical Practice Guideline is to promote a long, smooth propulsive stroke as seen in the semicircular pattern (Figure 4A) as opposed to the arcing (Figure 4B) which is characterised by very short strokes (Consortium for Spinal Cord Medicine 2005).

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Figure 4 Example of stroke patterns: A = semicircular pattern; B = arcing pattern (Consortium for Spinal Cord Medicine 2005).

From this collective pool of work, common threads regarding optimal set-up have begun to emerge. The recommendation for rear wheel position is to have the wheel as far forward as possible without rendering the wheelchair too unstable for the user to be able to function safely in the home environment (Consortium for Spinal Cord Medicine 2005). Hills (2010) in her thesis on wheelchair stability, found this to generally equate to a 20/80 distribution of weight between the front castors and rear wheels. In terms of the vertical adjustment of the rear wheel, which determines the height of the seat in relation to the wheels, a commonly used clinical 'rule of thumb' is to have the middle

finger of the user touch the centre of the rear wheel. This corresponds to 60° - 80° of elbow flexion with the hand resting on the apex of the wheel. Or, as described by van der Woude *et al.* (1989), 100° - 120° of elbow extension. Seat height in relation to the rear wheels is illustrated in Figure 5.

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Figure 5. Wheelchair seat height adjustment: A = Seat too low/axle too high; B = recommended angle (Q2= 100-120°); C = seat too high/axle too low (Consortium for Spinal Cord Medicine 2005).

The establishment of the SmartWheel User Group (SWUG) in 2004 has enabled researchers worldwide to contribute data to a shared, confidential database to help improve clinical services and expand research data sources (Cooper 2009). An analysis of experiences from this user group has now provided researchers with a proposed clinical framework, the SmartWheel protocol, for future research into manual wheelchair propulsion (Cowan *et al.* 2008).

These recommendations for wheelchair set-up and the SmartWheel protocol helped inform the design of the propulsion biomechanics aspect of this thesis.

2.6 Manual wheelchair propulsion and shoulder pain

As people with SCI survive into older age, they are exposed not only to the usual problems associated with ageing but also to problems of overuse injuries to the upper limb. A whole new discipline within medicine has now evolved around the concept of ageing with disability. It is important to recognise that in this context ageing does not necessarily refer to the chronological age of the

individual. It also encompasses the problems associated with living with a disability for many years. Most 50 year olds would not consider themselves old. However, if a 50 year old sustained a SCI at the age of 20 and has spent the last 30 years as a manual wheelchair user, it is likely that there will be signs of degenerative changes in joints and symptoms of overuse injuries beyond what would normally be associated with that age.

Research has tended to focus on two areas: the wrist and the shoulder. Problems relating to the wrist usually present as carpal tunnel syndrome (CTS) where the underlying pathology is damage to the median nerve. In the shoulder, the pathology is more complex and can include bicipital tendinitis, impingement syndrome, capsulitis, osteoarthritis and rotator cuff tears (Consortium for Spinal Cord Medicine 2005). The underlying cause of shoulder pain is associated with glenohumeral instability due to muscle imbalance (van Drongelen et al. 2006). Many of the activities performed by a manual wheelchair user will tend to strengthen the anterior aspect of the shoulder, e.g. propulsion, transfer, lifting up for re-positioning in the wheelchair or on the bed. This is particularly evident in low tetraplegics (C6-8) who either lack or have poor muscle stabilisation of the scapulae.

Although these overuse injuries are relatively routine to treat in the able bodied population, they have huge implications for a wheelchair user with rapid loss of independence due to pain and decreasing range of motion in joints. As a manual wheelchair user is unable to 'rest' the affected limb, once a problem has established itself, it will often progress to surgery more quickly. If surgery is undertaken, it requires hospitalisation for as long as the limb is immobilised and/or an increased care package at home to assist with transfers and other aspects of activities of daily living (ADL). This additional care package will need to remain in place till the individual is fully restored to previous level of independence. Powered mobility will be required for the duration of the recovery period and additional rehabilitation is likely to be required to regain skills. The total cost to the NHS of treating these injuries is therefore considerably more than for the able-bodied population.

The reported prevalence of upper limb problems varies greatly from study to study. For the purpose of this thesis only the literature relating to shoulder pain will be reviewed. An overview of some of the literature is outlined in Table 1.

Table 1. Studies into the prevalence of shoulder pain in people with SCI. CTS = Carpal Tunnel Syndrome. AC = Acromioclavicular. GH = Glenohumeral.

Author / year of publication	Population studied (N)	Time since injury Inclusion criteria	Investigations Outcome measures used	Prevalence of shoulder pain
Nichols, 1979	Paraplegic + Tetraplegic N= 517	Median: 7 year	Questionnaire	51%
Gellman, 1988	Paraplegic N= 84	> 1 yr	Interview Exam (CTS)+ X-Ray if symptomatic	35%
Pentland & Twomey, 1994	Paraplegic N = 52	Mean: 17 years	Symptom survey	39%
Curtis, 1999	Para = 103 Tetra = 92	1-13 yrs min 3 hrs/week manual w.ch.use	Medical history Questionnaire WUSPI	Para: 42% Tetra: 59%
Ballinger, 2000	Para + tetra N = 89 (male only)	>9 mths 1 - 48 yrs Aver: 10 yrs	FIM; CHART ROM Exam Radiographs (AC; GH)	30%
Boninger, 2001	Paraplegic N = 28	Mean = 11.5 yrs	Questionnaire Examination of shld MRI of shoulder	32%
Alm, 2008	Paraplegic (Thoracic) N = 88	1 - 47 yrs Full-time users	Questionnaire WUSPI	40%

The wide range in reported prevalence of shoulder pain (30-59%) might be explained by the varied size of the samples studied (28 to 517). Each study has a slightly different bias and therefore employs different investigations for the collection of the data. Most of the studies concentrate on paraplegics only and do not necessarily consist of full-time manual wheelchair users. A brief summary of the main findings of the above studies is given in the next section.

In the largest (and earliest) study by Nichols *et al.* (1979), 93% of the participants were manual wheelchair users; for all or some of the time 6% used powered mobility and 18% were able to ambulate with crutches. In this study just over half the study population reported having experienced episodes of shoulder pain. These were found to be more frequent and lasting longer with increased length of time since injury and a tendency to becoming bilateral was identified. This study laid the foundation for future studies as well as first coining the term 'wheelchair user's shoulder'. It is the only published study of a UK based population. Time since injury was also found to be associated with the presence of shoulder pain in the studies carried out by Gellman *et al.* (1988) and Pentland & Twomey (1994) whereas Curtis *et al.* (1999a) found no association with duration of wheelchair use and shoulder pain. The study by Curtis *et al.* (1999a) did however find an increase in pain with increasing age. Using the Wheelchair User's Shoulder Pain Index (WUSPI), which is a published and validated outcome measure (Curtis *et al.* 1995), this study was able to identify the activities that the participants found most painful. The WUSPI comprises 15 activities of daily living (ADL) which are scored on a 10 cm visual analogue scale (VAS). The activities identified as being the most painful were pushing the wheelchair up an incline, pushing the wheelchair for more than 10 minutes and sleeping. This study also established that tetraplegics seem to experience a greater intensity of shoulder pain than paraplegics. It should be noted though that the participants in this study were not exclusively full-time manual wheelchair users. The inclusion criterion was a minimum of 3 hours of manual wheelchair use per week. Ballinger *et al.* (2000) studied eighty-nine males with SCI at two time points, with a 3 year interval, in an attempt to identify the factors which might predict problems with loss of range of motion (ROM) and shoulder pain. Outcome measures used were

radiographs of the acromioclavicular (AC) and glenohumeral (GH) joints, Functional Independence Measure (FIM) and the Craig Handicap Assessment and Reporting Technique (CHART). Not surprisingly men with shoulder pain were more likely to also have problems with decreased ROM. Those who had ROM problems reported lower FIM scores whereas those with shoulder pain reported lower CHART mobility scores. Radiographic findings, e.g. joint narrowing, were found to be predictive of ROM problems 3 years later but not predictive of shoulder pain. Although Boninger *et al.* (2001) set out to investigate rotator cuff tears (RCT) using magnetic resonance imaging (MRI) in a group of 28 paraplegics, they only identified one RCT and found no relationship between shoulder pain and imaging abnormalities. They did however find a significant relationship between imaging abnormalities and body mass index (BMI). In a previous study, bodyweight had also been linked to median nerve injury (Boninger *et al.* 1999). In a more recent study by Alm *et al.* (2008), 18% of the full-time participants used a combination of manual and powered mobility. Although this study also found a relationship between increasing age and shoulder pain, the activities identified as causing most pain differed from those identified in the study by Curtis *et al.* (1999a). As well as pushing up inclines, loading the wheelchair into the car, lifting objects down from an overhead shelf and transferring from a wheelchair into a car were identified as causing the participants most pain.

The link between shoulder pain and BMI supports the recommendation to provide lighter wheelchairs as an integral part of a strategy to minimise the risk of overuse injuries to the upper limb (Consortium for Spinal Cord Medicine 2005). However, no study has studied the influence of the type of wheelchair, i.e. folding versus rigid frame, on shoulder pain in full-time manual wheelchair users. The final part of this thesis attempts to fill this gap.

In order to evaluate how the changes to Wheelchair Service delivery and provision have impacted on meeting the provision needs of people with SCI, two national surveys were conducted covering similar periods before and after the introduction of the wheelchair voucher scheme in England. The findings from the first survey informed the aim to investigate further the biomechanics of

wheelchair propulsion in the first year post discharge. The absence of up-to-date shoulder pain data for the UK informed the study to establish the prevalence of shoulder pain in a population with SCI and investigate this in relation to the type of wheelchair used.

From this, the research objectives of this thesis are defined as:

1. To evaluate changes in wheelchair provision to people with SCI in England between 1991 and 2004.
2. To investigate changes in propulsion biomechanics in a group of individuals with SCI in the first year post discharge and to identify key parameters for future study.
3. To establish the prevalence of shoulder pain and to investigate the relationship between the types of wheelchairs used and the severity of shoulder pain in people with SCI in the UK less than 10 years post injury.

3 METHODOLOGY

This chapter outlines the methods employed in the execution of the three aspects of this thesis.

Section 3.1 describes the methods applied to the two national surveys evaluating changes in wheelchair provision to people with SCI in England before and after the introduction of the voucher scheme.

Section 3.2 relates to the pilot study investigating changes in propulsion biomechanics during the first year post-discharge in a cohort of newly discharged individuals with SCI.

Section 3.3 outlines the additional factors which apply to the study establishing the prevalence of shoulder pain in people with SCI in the UK up to 10 years post onset and investigating the impact of wheelchair type on the severity of shoulder pain.

3.1 Wheelchair Provision Surveys

Two national surveys were carried out in collaboration with the UK SCICs in response to a series of changes in the Wheelchair Service delivery system in the UK during the 1990s and due to a growing demand from users for the new generation of wheelchairs which had become available over the same period of time.

3.1.1 Study Design

A postal questionnaire design was chosen for collecting the data for two national surveys to investigate wheelchair provision to people with SCI before and after the introduction of the Voucher Scheme in England ([Appendix 1](#)).

3.1.2 Development of questionnaire

The core sections of the questionnaires were the same with some additions to the 1998-2004 in response to the experience and outcome of the 1991-1997 survey (Rose LS et al. 2002). Information relating to 'other' wheelchairs used

was included in the 1991-1997 survey but subsequently dropped from the 1998-2004 survey as it did not yield clinically relevant information.

The questionnaires were designed with a tick box layout to make the completion of the questionnaire as easy as possible for the respondents ([Appendix 1](#)). The different sections of the questionnaire are described in more detail below.

3.1.2.1 Demographics and SCI characteristics

The groupings used for analysis of age and level of injury in the 1991-1997 survey were incorporated into the 1998-2004 questionnaire for easier completion and analysis. For the purpose of analysis, age was divided into groups of 20 year intervals: 0-19; 20-39; 40-59; 60-79 and > 80.

Neurological level of injury was grouped according to functional expectations in relation to wheelchair propulsion: C1-3, C4-5, C6-8, T1-6, T7-12 and L1-5. The initials 'C', 'T' and 'L' refer to the area of the spine involved, i.e. cervical (C), thoracic (T) and lumbar (L). The number following these initials indicates the lowest intact spinal segment, e.g. a person with C5 tetraplegia would have normal innervation down to and including the fifth cervical segment (ASIA 2011). In terms of wheelchair use, persons with levels of C1-3 are likely to be ventilator dependent powered wheelchair users. Although people with levels at C4-5 would have some upper limb function this would be limited to shoulder elevation and abduction with elbow flexion and supination. There are very few individuals at this level who would have effective manual wheelchair propulsion. At the C6-8 levels the function gained is wrist extension (C6), elbow extension and wrist flexion (C7) with finger-flexion and extension (C8). This group has the potential for completely independent self-propulsion indoors and out, although advanced wheelchair skills may be limited due to weak hand-function. T1-6 and T7-12 levels would all expect to be highly independent in their wheelchairs, the main difference being reduced trunk stability in the T1-6 group due to impaired innervation of the abdominal muscles. Levels of L1-5 may have some degree of ability to stand or ambulate and may not be totally dependent on their wheelchair. All groups from C6 and below would have the potential to take the

wheelchair in and out of the car independently. Users with good hand-function and no upper limb problems would also be introduced to techniques for going up and down stairs in the wheelchair with minimal or no assistance.

3.1.2.2 *Wheelchair type and use*

From a list of the most commonly used manual wheelchairs at the time of the 1991-1997 survey, the respondents were asked to select which type of wheelchair had been issued at the time of discharge ('first'). For the purpose of analysis the wheelchairs were grouped according to wheelchair frame type and the degree of rear axle adjustability and this classification was subsequently used with the 1998-2004 questionnaire. The guide to wheelchair groups is appended with photographic examples of each category in [Appendix 1.3](#).

In the 1998-2004 survey 'first' was used to describe the first long-term provision as opposed to 'interim' provision which was used to describe a wheelchair issued on discharge for short-term use only. Interim provision would typically be used to enable a patient to be discharged home without delay whilst awaiting delivery of a wheelchair on order or to keep them independent whilst awaiting follow-up assessment for permanent provision of wheelchair. The inclusion of a section on 'interim' use in the 1998-2004 survey was in response to the findings of the 1991-1997 survey.

The term 'present' was used in both surveys to describe the type of wheelchair used at the time of participating in the surveys.

Although the wording differed slightly in the two surveys, respondents were asked to indicate how much they depended on the wheelchair for their mobility. From this it was possible to identify those who were full-time users.

3.1.2.3 *Change of wheelchair*

Where the type of wheelchair used had been changed between discharge and the time of the survey, the respondent was asked to indicate how soon after discharge this change had taken place and the reasons for change.

As the surveys covered the lifetime of a wheelchair (~ 5 years), there was a possibility that respondents might indicate a change in wheelchair due to a need to simply replace the current wheelchair. For a change to be accepted for the purpose of this study, all responses were screened to make sure that there was a difference in the classification of the first and present wheelchair.

3.1.2.4 Funding sources

A key element of the surveys was to investigate funding sources for the wheelchairs used. The respondent was asked to identify how each wheelchair had been funded. The choices were the Wheelchair Service only, private/family/friends, charity and Placement Assessment Counselling Team (PACT) or Access to Work⁵. The partnership and independent voucher options were added for the 1998-2004 survey.

3.1.2.5 Wheelchair assessment

Information was collected relating to which professionals were involved in the wheelchair assessment, i.e. the spinal therapist, Wheelchair Service therapist, dealer. Respondents were able to tick more than one so it was possible to get an indication of levels of collaboration between professional groups.

3.1.2.6 Wheelchair Service

In order to be able to assess geographical differences in wheelchair provision the respondents were asked to give the name of their Wheelchair Service.

3.1.2.7 Adjustments and user satisfaction

In response to the findings of the 1991-1997 survey, sections relating to adjustments carried out to the wheelchair and user satisfaction with provision for 'first' and 'present' wheelchairs were included in the 1998-2004 questionnaire.

⁵ PACT/Access to Work: This is a UK government funded scheme which will help fund any type of equipment that will enable a person with a disability to continue working.

Anecdotal experience from the out-patient reviews following discharge from the SCIC is that wheelchairs with adjustable rear axle plate were supplied without the rear wheel position being adjusted. In order to assess how widespread this problem was, if at all, a section was included on whether the wheelchair had been adjusted on handover and if so who had adjusted the wheelchair.

3.1.3 *Statistical advice*

There was no access to statistical advice at the time of the 1991-1997 survey.

Advice was sought and granted from the Thames Valley Office of Public Health in Oxford in the design of the questionnaire and execution of the 1998-2004 survey. No changes were recommended.

3.1.4 *Recruitment of local investigators*

As the target group were individuals with SCI, a letter was sent to the consultants in all the UK SCICs asking for permission to approach their patients. Once this permission had been granted, the therapy departments were approached to identify a clinician who would be willing to become the local investigator and be responsible for identification of suitable subjects and the administration of the questionnaires.

The participating SCICs in the 1991-1997 survey were all centres in England (8) plus the regional centres in Scotland, Northern Ireland and Wales, eleven in total. For the 1998-2004 survey the regional centre in Wales was unable to take part.

3.1.5 *Ethical Approval*

Ethical advice was sought from the Thames Valley Local Research and Ethics Committee for the 1991-1997 survey, but ethical approval was not required.

As chief investigator, the researcher registered the 1998-2004 survey with the Research and Development (R&D) Office of Buckinghamshire Hospitals NHS Trust. Application for ethical approval for a multi-centre study was submitted in July 2005 according to the COREC approved system and granted from Oxford

REC B in September 2005. As all age groups were included in the study additional documentation for children had to be included. All ethical documentation can be viewed in [Appendix 1](#).

3.1.6 Inclusion criteria

Inclusion criteria for participants were as follows:

1. First time rehabilitation undertaken at a UK SCIC
2. Living in the UK and entitled to NHS provision
3. Using a manual wheelchair at the time of discharge
4. Discharged from the SCIC between 1.1.1991 and 1.8.1997 or between 1.1.1998 and 31.12.2004

The changes taking place within the Wheelchair Service delivery system created a natural timeframe for the surveys. The original date for the Voucher Scheme to be implemented was August 1997. The time from the devolution of the Wheelchair Services on 1 January 1991 to the introduction of the Voucher Scheme in 1997 determined the period covered by the 1991-1997 survey. The subsequent survey covered a similar length of time following the introduction of the Voucher Scheme, 1998-2004.

As the Voucher Scheme was introduced over a period of time in 1997, the respondents from the 1991-1997 survey were screened to make sure that they had not used a voucher for any provision. The start date of 1.1.1998 for the follow-up survey was to ensure that there was no duplication of participants from 1997 in the two surveys.

3.1.7 Confidentiality and consent

Confidentiality was ensured by the local investigator at each SCIC identifying the subjects who fulfilled the inclusion criteria, allocating the unique subject number and posting of the questionnaires.

Consent to participate was assumed by completion of questionnaire.

3.1.8 Recruitment of subjects

In total, 2602 individuals were identified as fulfilling the inclusion criteria for the 1991-1997 survey. Posting of the questionnaires took place during the second half of 1998. No reminders were sent. Of the 1088 questionnaires returned, 149 were rejected as non-valid, leaving a study sample of 939 subjects, an effective response rate of 36%.

For the 1998-2004 survey, 2798 questionnaires were posted from June 2006 onwards thereby ensuring that all potential respondents had been discharged for a minimum of 12 months. The reason not to approach people until they had been discharged for a full year was based on the findings from the 1991-1997 survey, i.e. large numbers changing their wheelchair within one year of discharge. Reminders were sent out 3 months after the initial questionnaire. Recruitment from all participating SCICs was completed by January 1, 2008. The valid responses totalled 1206, giving an effective response rate of 43%.

Both surveys used prepaid self addressed envelopes. All replies were sent directly to the chief investigator for data entry and analysis.

As the Voucher Scheme only applies to England, the data was filtered to include only full-time manual wheelchair users discharged from a SCIC in England.

Full-time was defined as using a wheelchair for both indoor and outdoor mobility.

Manual wheelchair user was defined as using a manual wheelchair at the time of taking part in the survey.

Hence some respondents included in the data analysis may have used powered mobility initially on discharge but later changed to using a manual wheelchair. Those respondents who used a manual wheelchair initially and later changed to using powered mobility were excluded from the analysis.

In total 526 subjects from the 1991-1997 survey were found to comply with these criteria and 550 from the 1998-2004 survey.

3.1.9 Funding for study

Funding was secured from the David Tolkien Award and the UK SCI Research Network (UKSCIRN).

3.1.10 Data entry and statistical analysis

The 1991-1997 questionnaires were converted to Teleform format after they had been returned and prior to data entry.

The questionnaire for the 1998-2004 survey was converted to Teleform format and piloted prior to posting.

Data was entered and manually verified using Teleform automatic forms processing system (version 10.4.1), and analysed using Microsoft Office Excel (2007) and SPSS (version 17.0).

Descriptive statistics (frequencies) were used for the analysis of the whole sample characteristics. Chi-square statistics and Wilcoxon signed-ranks test were used to test for statistical significance.

Level of significance was set at $p < 0.05$.

3.2 Propulsion Biomechanics

3.2.1 Study design

The aim of this pilot study was to investigate changes in propulsion biomechanics in a cohort of new spinal cord injured wheelchair users during the first year post-discharge in order to identify the key parameters to be used in a future, larger study.

Participants were recruited from two Spinal Cord Injury Centres.

3.2.2 Ethical approval

This study was covered by the ethical approval granted by the Royal National Orthopaedic Hospital (RNOH) Trust Ethics Committee to a wider study carried out at ASPIRE Centre for Disability Sciences at Stanmore under the leadership of Professor Martin Ferguson-Pell.

All documentation relating to consent and participation can be viewed in [Appendix 2](#).

The study was also registered with and approved by the R&D Office at Buckinghamshire Hospitals NHS Trust to enable recruitment of participants from the SCIC at Stoke Mandeville Hospital.

3.2.3 Inclusion criteria

The study participants had to fulfil the following criteria:

1. have a spinal cord injury
2. be a manual wheelchair user
3. have no history of previous or present upper limb pain

Two study groups were used, one comprising new wheelchair users (SCI less than 2 years) and one with experienced wheelchair users (SCI more than 2 years).

3.2.4 Recruitment

The new wheelchair users were recruited amongst patients due to be discharged from the London Spinal Cord Injuries Centre (LSCIC) at the Royal National Orthopaedic Hospital, Stanmore and from the National Spinal Injuries Centre (NSIC) at Stoke Mandeville Hospital, Aylesbury.

In total 19 individuals gave their consent to participate and they constitute the study group.

For the purpose of comparison, a convenience sample of experienced users was recruited via the ASPIRE Centre at Stanmore and the LSCIC at Stanmore. The experienced users were matched for age, gender and level as far as possible within the timeframe of the study.

In total, 10 experienced users gave their consent to participate.

3.2.5 Experimental protocol

3.2.5.1 Assessment intervals

It was initially intended that participants would be assessed within one month of discharge, referred to as time '0' (T0). During the recruitment phase of the study it quickly became clear that it was very difficult for participants to attend initially on discharge. T0 was changed to be immediately prior to actual discharge while they were still in-patients.

Repeat testing was scheduled for 6 months after the initial test, referred to as T6. Thirteen participants were available for re-testing at T6. However, as one of these subjects had not been able to complete all aspects of the testing at T0, complete datasets for T0 and T6 were only available for 12 participants.

3.2.5.2 Physical assessment

Each participant was assessed according to the form designed for this study ([Appendix 2.7](#)).

At T0 all participants were screened for compliance with the inclusion and exclusion criteria and the consent form was signed. Personal information was

entered including information pertaining to housing and employment situation. This information has not been used in this thesis.

A screening of posture was carried out in the person's own wheelchair to establish their pelvic and trunk posture. If the participant was not seated with good posture, corrections to the posture would be suggested and implemented if possible and appropriate.

Good posture was defined as being symmetrical in the anterior/posterior view with no pelvic obliquity/rotation, no deviation of the spinal curves (scoliosis) and with the head aligned centrally. In the lateral view, the trunk should be upright with normal spinal curves and the pelvis in neutral position.

Each participant was also assessed in supine on a plinth in order to assess free hip flexion with pelvis fixed. This particular measurement was important in order to help determine optimal wheelchair configuration.

The assessment was repeated at T6.

All participants were found to have good posture and no changes were made.

3.2.5.3 *Wheelchair configuration.*

The configuration of the wheelchair provided for discharge was recorded in some detail and recorded on the assessment form:

1. An inclinometer was used to measure all angles (seat, back, castor housing).
2. A metal tape was used to measure all dimensions (seat width, depth and backrest height) and perpendicular distance to the floor at the front and back corners of the seat canvas.
3. The position of the rear wheel axle sleeve in the axle plate was measured from the back upright of the frame to the centre of the locator.
4. The wheelbase was measured from the front contact point of the castor tyre on the floor to the rear contact point of the rear wheel tyre on the floor.

5. If the wheelchair configuration was considered not to be optimal⁶ for the user, it would be modified according to recommendations from published studies or, in the absence of any published recommendations, according to the researcher's clinical experience.

As mentioned in [Chapter 1](#), the main reason given for abandoning the wheelchair early was 'pushability'. For the users with a basic wheelchair this might be linked to sub-optimal wheelchair configuration and poor propulsion biomechanics. For those who had been issued with a lightweight, customizable wheelchair and still abandoned it within one year of discharge, this might be a reflection of a lack of understanding of the scope of adjustment possible within the wheelchair. In order to investigate this, the protocol for the propulsion study allowed for optimisation of the wheelchair configuration if this was felt to be appropriate.

Optimal configuration was defined as:

1. *Rear wheel axle position – forward:* as far forward as possible without compromising the stability of the user (Consortium for Spinal Cord Medicine 2005). Example of axle plate with rear wheel receiver in mid-position is shown in Figure 6.



Figure 6 Quickie GPV axle plate with receiver for rear wheel.

2. *Rear wheel axle position - vertically:* when moving the axle plate up or down relative to the seat unit of the wheelchair, the distance between the

⁶ In the clinical setting 'optimal' or 'optimisation' is used widely to describe a wheelchair which has been configured to meet an individual's seating needs based on posture, comfort and function at that time.

centre of the wheel to the shoulder is altered. This is usually referred to as the seat height. The recommendation is that the fingertip of the middle finger should reach the centre of the rear wheel (Consortium for Spinal Cord Medicine 2005). This equates to 60° - 80° of elbow flexion with the hand on the apex of the rear wheel or an angle of 100° - 120° between the upper arm and forearm (see Figure 5 B, [Chapter 2.5](#)) (van der Woude et al. 1989).

3. *Seat angle*⁷: this is the drop of the seat at the back in relation to the front of the seat. This is usually determined by comfort (Desroches G et al. 2006) and functional ability to move forward and backward on seat. As this places the buttocks lower relative to the knees, this set-up will make it easier for the user to position himself at the back of the seat – and stay there. If this angle is too steep it may make it difficult for the less able user to get forward on the seat, e.g. as in preparation for a transfer.
4. *Backrest angle*: Hastings *et al.* (2003) recommend that the backrest should be as close to vertical as possible without compromising free use of both arms. A test to ensure that upper limb function has not been compromised is to check if the participant is able to lift both arms up to 90° of shoulder flexion without falling forward.
5. *Backrest/seat angle*: this is determined by the available range of free hip flexion (tested in supine as described in [Chapter 3.2.5.2](#)).
6. *Backrest height*: there is no specific evidence to guide determination of backrest height. It rests with the clinician and the user to make the decision based on function and posture. In SCI rehabilitation, clinical practice for new users is to have the backrest to the level of sensation but no higher than the inferior angle of the scapulae to allow free movement of the shoulder girdle during manual propulsion (Rose 2006).
7. *Footplate height*: the footplate(s) should be adjusted so that the full length of the thigh is supported by the seat (cushion).

⁷ Seat angle may also be referred to as seat inclination, seat rake, bucket or 'dump'.

The ultimate aim is for the person to be supported in a posture with a virtual plumbline falling vertically from ear through shoulder, through hip (trochanter) and in line with or just behind the centre of the wheel (Figure 7).

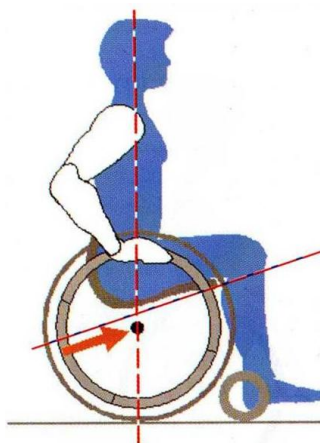


Figure 7 Optimization of wheelchair. Reproduced with permission from Bengt Engstrom. (Engstrom 2002)

As moving the rear wheel forward to any degree will alter the weight distribution between the front castors and the rear wheels, any change in configuration must always be followed by a test of stability with the user in the wheelchair. Although no changes⁸ were made to the wheelchair configuration of the participants in this study, the stability of the configuration was tested for each participant prior to entering the propulsion part of the protocol. To check the stability of the wheelchair, each participant was asked to lift both arms above the head and try to rock backwards. The castors were allowed to off-load but not clear the floor for the chair to be deemed stable.

Based on the findings from the first wheelchair survey (Rose et al. 2002a) it was anticipated that the participants would be provided with a wheelchair selected from a wide range of wheelchair designs and might potentially change the wheelchair within the timeframe of the study. To control for this, it was decided to perform the tests in the participants own chair as well as in a control chair.

⁸ For one participant it was suggested after completion of the T6 testing that the rear wheel was moved forward. With the participant's consent and after checking the stability in the laboratory setting, the participant returned home. He later reported that rear wheel had been returned to its original position because the chair was too unstable for the community setting in which he lived.

The control chair in this study was a Quickie GPV (Figure 8). This is a rigid frame lightweight wheelchair and was chosen because it has a good range of rear wheel, backrest angle and backrest height adjustability and was timely to adjust. A further important consideration was that it is regularly issued from Wheelchair Services. The control chair was adjusted to a set-up as similar as was physically possible to the set-up of the participant's own chair.

As no optimisation was indicated, the wheelchair configuration at T0 and T6 remained the same.



Figure 8 Quickie GPV (control wheelchair). [Sunrise Medical](#).

The wheelchairs were standardised with 3° of camber.

The experienced wheelchair users followed the same protocol but were only assessed and tested on one occasion.

3.2.6 Data collection

The propulsion data was collected using the [SmartWheel](#) (Figure 9), following the SmartWheel protocol ([Appendix 2.6](#)). This is a standard clinical protocol which describes the testing of manual wheelchair users over four different terrains: level tile (Lino), low pile carpet, up a 1:12 ramp and performing a figure-of-eight on level tile.

Only two out of the four terrains have been chosen for the purpose of this thesis:

1. straight push on a smooth, level surface (Lino) for 12 m and
2. propelling up a 10 m, 1:12 ramp

The steepness of the ramp (1:12) complies with the maximum rise recommended by building standards. This corresponds to a 5° slope.

These two aspects of the protocol were chosen as they represent the extremes of propulsion, the easiest and the hardest. The test for each terrain was repeated three times. To avoid the influence of fatigue on the test results, a rest period between the tests in own chair and control chair was incorporated into the protocol. The tests were carried out in the same order for all participants with the test on lino first, followed by the test on the ramp.

Data was analysed for the steady state phase as recommended in the SmartWheel protocol.



Figure 9 SmartWheel mounted on Quickie GPV.

The SmartWheel was fitted to the non-dominant side of the wheelchair. As the SmartWheel has a larger diameter (25 inches) than a standard rear wheel (24 inches) and is fitted with a solid tyre, the opposite wheel was also replaced with a 25" solid tyre wheel. Although solid tyres have been found to increase rolling resistance (Sawatzky et al. 2004) using wheels fitted with solid tyres ensured that pressure did not change during testing and between subjects.

Although the SmartWheel was expected to be interchangeable with most wheelchairs, it was found that the SmartWheel did not locate properly into the receiver in some axle plates. A special universal sleeve was manufactured by Three Rivers Holdings and supplied to overcome this problem and is now routinely supplied by them for wheelchairs with axles manufactured in metric and imperial units.

An illustration of a typical output from a SmartWheel test for Lino and Slope are presented in Figure 10 and Figure 11.

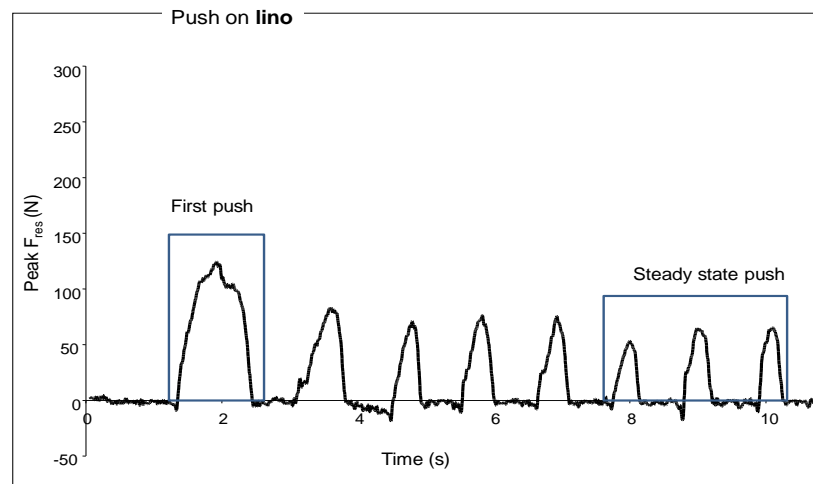


Figure 10 Illustration of a SmartWheel output for test on Lino.

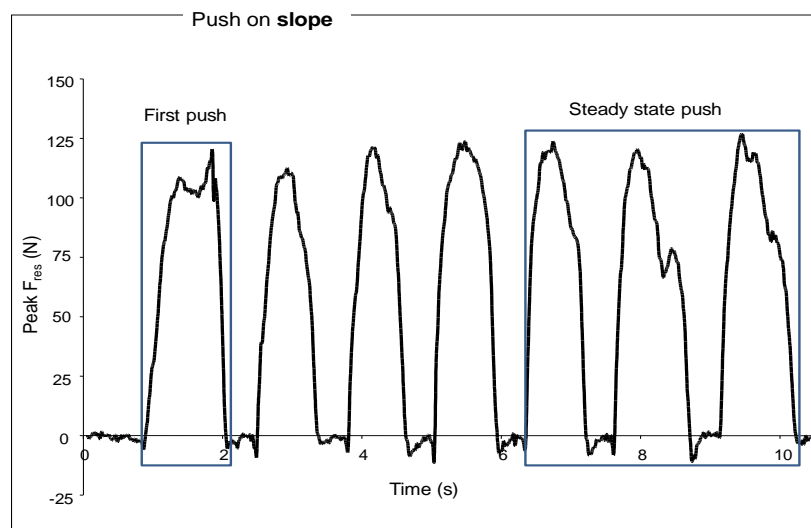


Figure 11 Illustration of a SmartWheel output for test on Slope⁹.

The recommendations from the SmartWheel User Group (SWUG) suggest four variables for analysis (Cowan et al. 2008):

⁹ 'Slope' and 'Ramp' are used interchangeably throughout text.

1. **Velocity** is the speed of travel of the wheelchair measured as m/sec. For community participation purposes, a speed of 1.06 m/s is required to safely cross a road. Participants were asked to propel at self-selected speeds.

2. **Stroke length** is the arc travelled by the hand from the moment of contact with the handrim to the point of release; measured in degrees (°). The recommendation from Clinical Practice Guidelines for the Preservation of Upper Limb Function (Consortium for Spinal Cord Medicine 2005) is for longer, smoother strokes to minimise the risk to the upper limb of repetitive strain injury.

3. **Push frequency** is defined as the frequency of contact with the pushrim during the entire activity tested, expressed as contacts (or strokes¹⁰) per second.

4. **Average peak resultant force** is calculated using the following equation

$$F_{res} = \sqrt{Fx^2 + Fy^2 + Fz^2}$$

This is the sum of all forces applied to the pushrim, i.e. in each of the three planes (x, y, and z). A diagram illustrating the forces and moments derived from the SmartWheel is presented in Figure 12. The tangential force (F_t) is calculated by the SmartWheel software by rotating the vectors F_x and F_y from the global reference frame into the handrim coordinate frame; it can also be calculated by dividing the moment about the rear axle by the radius of the pushrim, where the force is applied (see Cooper et al. 1997 for a full discussion on the difference between the two methods). The tangential force was not used in this study as the average peak resultant force (F_{res}) was thought to be more representative of the user's effort as it represents all force applied by the user to the pushrim including those not directly necessary for forward movement of the wheelchair but used in generating the tangential force. F_{res} is calculated automatically (sampled at 240Hz) by the SmartWheel software and measured in Newtons.

¹⁰ Stroke: used to describe a push performed by the user on the rear wheel. 'Push' and 'stroke' are used interchangeably throughout the text.

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Figure 12 Diagram illustrating the forces (F) and moments (M) measured by the SmartWheel: F_y = vertical force, F_z = medial lateral force, F_x = horizontal force, F_t = tangential force and F_r = radial force. 'M' is the moment around the respective forces (Boninger et al. 1997).

The most recent recommendation from the SmartWheel User Group is to weight normalise the force by dividing the Peak F_{res} output by the user's weight (Cowan et al. 2008). Both measures were used in this study.

All tests were timed and repeated three times. More than three repetitions might be desirable in order to establish a more robust typical value for each test. However, repeating each test more than three times in this user group would introduce a risk of fatigue and hence compromise the results. Furthermore, this choice of method complies with recommended practice for studies using the SmartWheel.

The SmartWheel measures forces in the range of $\pm 155\text{N}$ and moments in the range of $\pm 77\text{Nm}$. The forces are measured with a precision of 0.6 N and a resolution of 1N and the moments are measured with a precision of 0.6 Nm and a resolution of 1Nm. The wheel angle is measured from 0° - 360° and has a precision of 0.18° and a resolution of 0.2° (Cooper et al. 1997b). Forces in the range of 18.6N to 74.5N were checked in a separate experiment, details of which can be found in [Appendix 2.7](#). The SmartWheel is designed to automatically re-calibrate at the beginning of each test ([Appendix 2.6](#)).

3.2.7 Data entry and analysis.

The findings from the SmartWheel User Group report have been used as the benchmark against which the results from this pilot study have been analysed.

The SmartWheel data is transmitted wirelessly to a computer running the Smartwheel Software Suite and also automatically saved on a memory card located in the SmartWheel itself. In this study, for simplicity of operation, the data was collected on the memory card only.

After completion of the trial, the data was downloaded onto a desktop computer using a SmartWheel conversion program and then into a spreadsheet using Microsoft Office Excel 2007 for further analysis. The processed data was then exported to SPSS (version 17.0) for statistical analysis.

This study represents pioneering work in this field as, to the best of the author's knowledge, no other published study is currently available, which compares a group of users over time or compares one group with another as in this study. Hence, no directly comparative data analysis was available.

Due to the limited sample size of this study, the number of available statistical tests is fairly limited and may be strongly influenced by outliers in the data sets. In general, the statistical tests are either parametric or non-parametric. Parametric tests assume that the data distribution follows a theoretical probability distribution function. Non-parametric tests on the other hand do not rely on data belonging to any particular distribution and covers techniques that do not assume that a structure of a model is fixed (Sheskin 2011). Due to the nature of the variables tested in this study (velocity, length, frequency and force) the data distribution should theoretically have a normal distribution. This was verified by carrying out an initial analysis of the data by plotting the data against a normal distribution curve and calculating the mean and median to give a further indication of any bias in the data. Where data distribution follows the standard bell shape (Gaussian distribution) and statistical analysis of the mean and median confirmed symmetry in the distribution, the data was taken to be parametric (Figure 13). If not, the data was taken to be non-parametric.

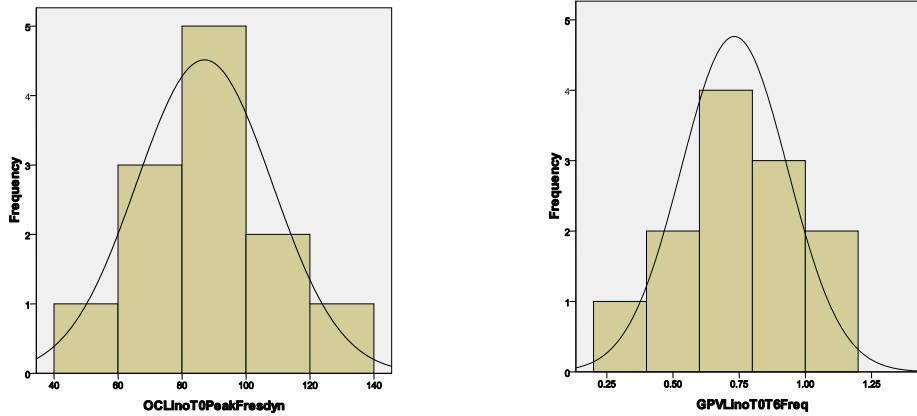


Figure 13 Normal distribution curves for new users for the test in own chair (OC) on Lino at T6 for F_{res} and in the GPV on lino at T6 for stroke frequency.

Descriptive statistics (frequencies) were used for the analysis of the whole sample characteristics such as age, gender and level.

The statistical significance of differences between conditions (slope and lino) for new wheelchair users, tested at two time points (T0 and T6) was carried out using statistical hypothesis testing with a level of significance set at $p < 0.05$.

For the parametric data sets the paired (dependent) t-tests was used and for the non-parametric data sets the equivalent Wilcoxon signed-ranks t-test was used. Only two data sets, stroke length in the GPV on Lino at T6 and stroke frequency in the GPV on the ramp at T6, failed the normal distribution tests. Hence, the Wilcoxon signed-ranks t-test was only used to test for statistical significance of differences in the test at T0 and T6 for these two variables (Figure 14).

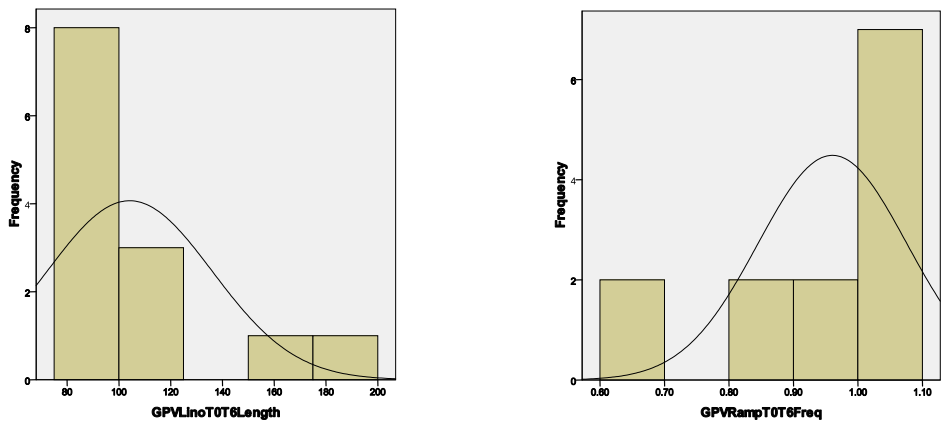


Figure 14 Normal distribution curves for new users for the test in GPV on Lino at T6 for stroke length and in the GPV on the ramp at T6 for stroke frequency.

Independent t-test was used to test for statistical significance of differences between new and experienced users as all the data was confirmed as having a normal distribution (Figure 15).

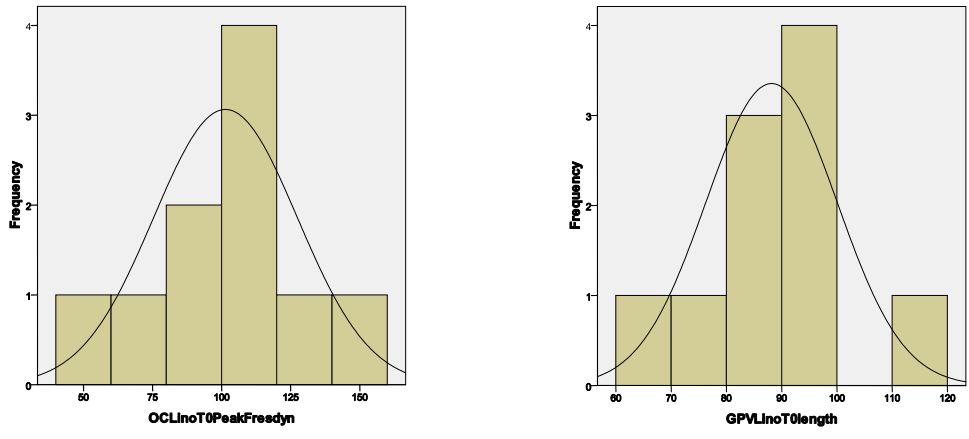


Figure 15 Normal distribution curves for experienced users for the test in own chair (OC) on Lino at T0 for F_{res} and for the test in GPV on Lino at T0 for stroke length.

3.3 Shoulder Pain

The purpose of this part of the thesis was to establish the prevalence of shoulder pain in people with SCI, living in the UK, less than 10 years post onset and investigate the impact of wheelchair type on the severity of shoulder pain. It is not an in-depth study of all the factors that might predispose a manual wheelchair user to develop shoulder pain.

3.3.1 Study design

The study population was recruited by inviting the participants in the 1998-2004 national survey ([Chapter 3.1](#)) to complete the Wheelchair User's Shoulder Pain Index (WUSPI). Those who returned a completed WUSPI were deemed to have consented to participate. In total 705 valid replies were received.

Participants were recruited from all the 10 SCICs taking part in the 1998-2004 survey, i.e. England, Scotland and Northern Ireland.

Only data from participants who were full-time manual wheelchair users at the time of the survey was used.

The same methodology applies as described for the wheelchair provision surveys ([Chapter 3.1](#)) with the addition of:

3.3.2 Outcome measure used

The WUSPI is a validated and published outcome measure (Curtis et al. 1995). It is a 10cm VAS with 'No pain' at one end and 'Worst pain ever experienced' at the other. The participant is asked to score the degree of shoulder pain experienced in the last week in 15 different activities by placing a X on the line. The activities relate to activities of daily living (ADL) as well as wheeled mobility. The form gives the respondent the option of scoring an activity as 'not performed'. The WUSPI does not specify left or right side. The wording of five of the items was adapted to meet local vocabulary standards while preserving the meaning of the original question. The full WUSPI form can be viewed in [Appendix 3.1](#).

3.3.3 Data entry and statistical analysis

For standardisation purposes, the centre of the X perpendicular to the line was the mark from which the measurement was taken. For the purpose of analysis the scores were grouped:

- 0 - 1cm was interpreted as 'no or negligible pain'
- 1.1- 4cm = minimal pain;
- 4.1 - 7cm = moderate pain and
- 7.1 - 10cm = severe pain.

The presence of pain was identified as the participant scoring > 1 cm on the scale in at least one variable.

In studies using the WUSPI, the scores for each individual across all 15 items are analysed, giving each participant a total pain score (Curtis et al. 1995). As tetraplegics are not likely to be able to carry out as many of the 15 activities as the paraplegics Curtis *et al.* (1999a) devised a method of correcting the tetraplegic pain score. For the purpose of this study each item was analysed separately and the group mean, median and standard deviation calculated for each item.

Data was analysed using Microsoft Office Excel (2007) and SPSS (version 17.0).

Descriptive statistics (frequencies) were used for the analysis of the whole sample characteristics. Chi-square statistics were used to test the relationship between selected variables and severity of pain.

Level of significance was set at $p < 0.05$.

This concludes the section on the methodologies used for all three aspects of this thesis.

4 RESULTS

This part presents the results from the three aspects of this thesis.

Section 4.1 presents the findings from the two national surveys of wheelchair provision to people with SCI in England covering the periods 1991-1997 and 1998-2004.

Section 4.2 refers to the results of the pilot study into changes in propulsion biomechanics in newly discharged people with SCI.

Section 4.3 concludes with the results from the study looking into the prevalence of shoulder pain in the UK and the impact of wheelchair type on shoulder pain in people with SCI.

4.1 Wheelchair Provision Surveys

Not all respondents completed all questions. The number of respondents (N) is given for each finding. Multiple responses were possible in some sections of the questionnaire.

Only full-time, manual wheelchair users discharged from a SCICs in England have been included.

When referring to types of wheelchairs, the classification used is the one described in [Chapter 3.1.2.2](#), and which can be viewed in [Appendix 1.3](#).

Percentages presented in the illustrations are rounded to whole numbers.

4.1.1 Demographics

The data relating to age, gender and level of lesion was found to be representative of the general SCI population. Age and level are presented in Table 2. As the age group '>80' was an addition to the 1998-04 survey and constitutes 1% of the whole sample, this group has been merged with the 60-79 yr group for presentation purposes here.

Table 2 Age and level of the participants in the two surveys, 1991-1997 and 1998-2004. ¹¹

AGE						
	0-19 yrs	20-39 yrs	40-59 yrs	> 60 yrs		
1991-97 (N= 526)	4%	51%	29%	16%		
1998-04 (N= 548)	1%	39%	37%	23%		
LEVEL						
	C1-3	C4-5	C6-8	T1-6	T7-12	L1-5
1991-97 (N= 447)	1%	11%	20%	22%	35%	11%
1998-04 (N= 513)	2%	12%	14%	28%	37%	7%

The gender distribution was 78% male / 22% female for 1991-97 and 75% / 25% for 1998-2004.

4.1.2 Wheelchair provision

Participants were asked to classify the type of wheelchair they used as ‘interim’ (i.e. the wheelchair issued on discharge for short-term use only), their first long-term wheelchair (‘first’) and the type of wheelchair they used at the time of taking part in the survey (‘present’) irrespective of how the wheelchair was funded or supplied. The results were analysed according to the [classification](#) of wheelchairs used with the questionnaire. The results for ‘first’ and ‘present’ wheelchairs are presented in Figure 16 and Figure 17.

¹¹The initials ‘C’, ‘T’ and ‘L’ refer to the part of the spinal cord affected by the spinal cord injury. C = Cervical; T = Thoracic; L = Lumbar. The numbers refer to the lowest unaffected spinal segment. This classification is used throughout document.

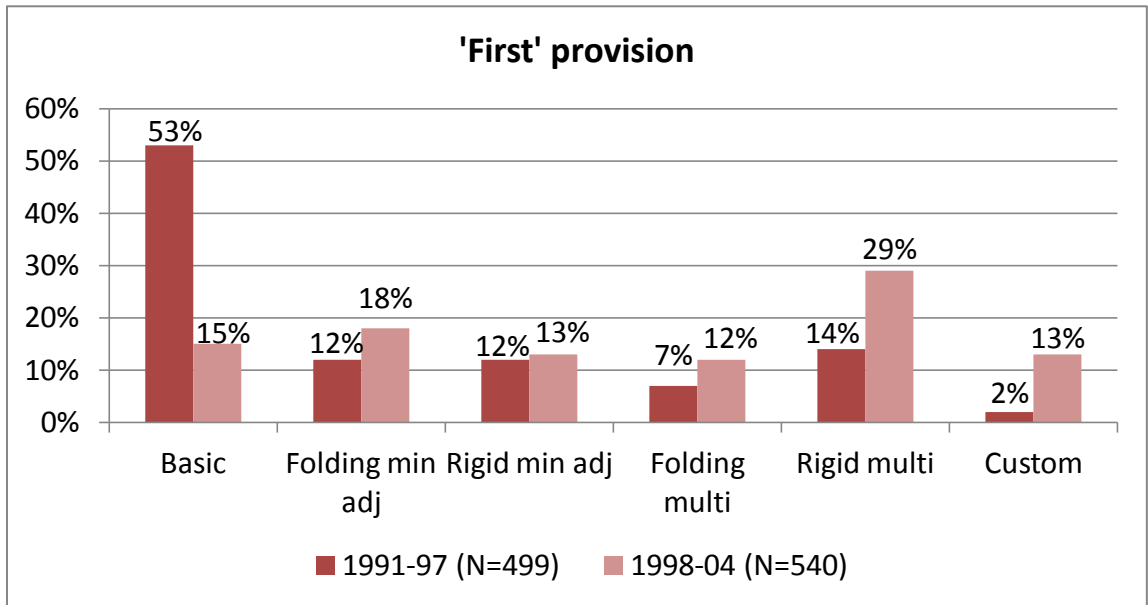


Figure 16 Types of wheelchairs provided as first long-term wheelchair. ¹²

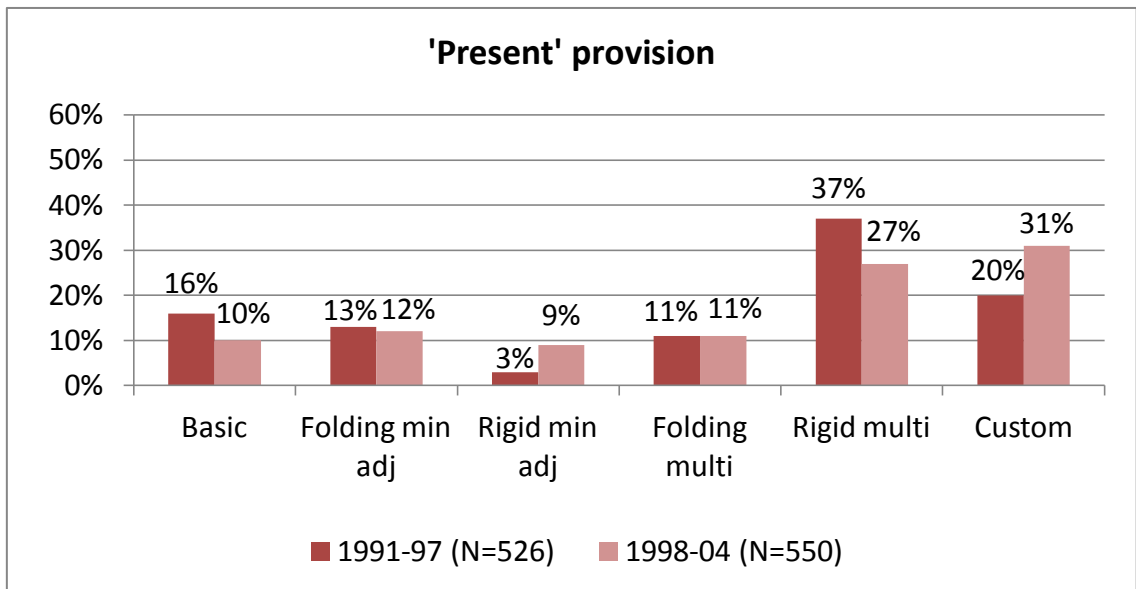


Figure 17 Types of wheelchairs used at the time of the surveys.

¹² 'Min.adj.' is minimally adjustable and 'multi' is multi adjustable, referring to the amount of possible adjustability of the rear wheel position. This classification is used throughout the document.

As interim provision was only adopted into clinical practice following the publication of the 1991-97 survey (Rose et al. 2002a), data is only available from the 1998-04 survey. Interim provision was found to be used in 62% of discharges. The distribution of types of wheelchairs supplied for interim use is presented in Figure 18.

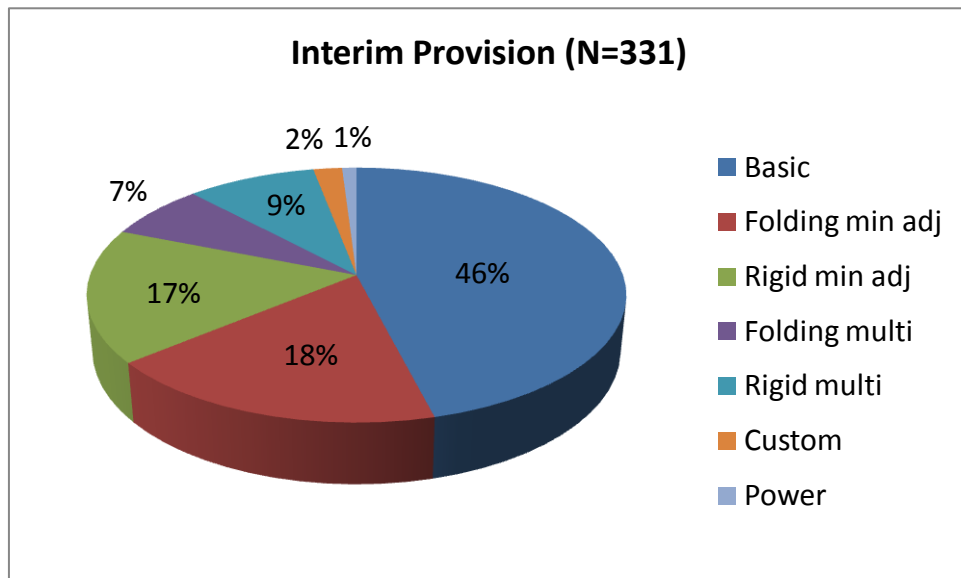


Figure 18 The types of wheelchairs supplied for interim use.

The interim wheelchairs were supplied primarily by Wheelchair Services (57%) with a further 36% supplied by the SCICs. The Red Cross supplied 1%. For the remainder, the respondents were unable to indicate who had supplied the wheelchair.

The participants who had been supplied with an interim wheelchair were asked to indicate the expected and actual duration of use of the interim wheelchair. The defined periods of use were: < 3 months, 3-6 months and > 6 months. Twenty-eight percent of respondents used it for longer than the expected 3 months and 22% used it for longer than the expected 3-6 months. In contrast 19% used it for less than the expected 6 months.

Of the 87 individuals who used an interim wheelchair for more than 6 months, 41% used a basic folding wheelchair.

4.1.3 Change of type of wheelchair used

Participants were asked if they had changed the type of wheelchair used as their first long-term wheelchair.

If the type of wheelchair used at the time of the survey was different to the type of wheelchair used as the 'first' wheelchair, the participants were asked to indicate how soon after discharge this change had taken place. The results for the two survey periods are illustrated in Figure 19.

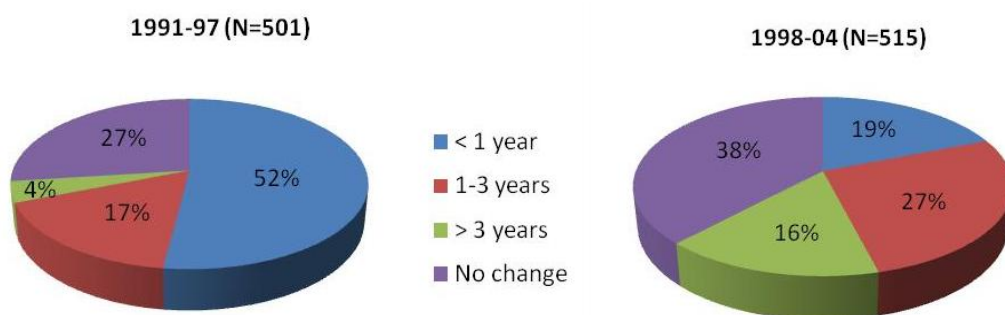


Figure 19 Interval between discharge and changing of the type of wheelchair used.

It is not generally recommended for an inexperienced user to have a custom-made wheelchair as their first long-term wheelchair. As the use of custom wheelchairs as a first wheelchair increased from 2% to 13%, further analysis was carried out to determine if any of the custom wheelchairs were changed within the lifetime of a voucher, i.e. 3-5 years. This showed that 36% of the custom wheelchairs used as first wheelchairs in the 1991-1997 survey were changed within 1 year of discharge; none were changed between 1-3 years. In the 1998-2004 period, 19% were changed within 1 year with a further 14% within 1-3 years of discharge.

In order to identify the characteristics of those most likely to change early, crosstabulation was performed using Chi-squared to test for statistical significance. 'Change' was crosstabulated with age, gender, level and first

wheelchair. For the 1991-97 survey the variables age and first wheelchair were found to be highly significant with $p < 0.001$ for both. In order to calculate the relative risk ratio 'change' was collapsed into 'change' and 'no change', 'age' was collapsed into '< 40 years' and '> 40 years'. The wheelchair groups were collapsed into 'standard' ([Groups 1,2,3](#)) and 'lightweight wheelchair' ([Groups 4,5,6](#)). The relative risk analysis for the 1991-97 data showed that those who were < 40 years were 1.5 times more likely to change than those > 40 years. The 95% confidence limits for this result suggest that this ratio is in the range 1.18 to 1.82. Those with a standard wheelchair were also 1.5 times more likely to change their wheelchair than those with a lightweight wheelchair. The 95% confidence limits for this result suggest that this ratio is in the range 1.27 to 1.72.

For the 1998-2004 survey the variables age and gender were found to be significant with $p=0.001$ and $p=0.049$ respectively. The relative risk analysis showed that those who were < 40 years were 1.5 times more likely to change than those who were > 40 years. The 95% confidence limits for this result suggest that this ratio is in the range 1.15 to 1.85. The relative risk analysis for gender showed that females were 1.5 times more likely to change than males. The 95% confidence limits for this result suggest that this ratio is in the range 1.0 to 2.2.

4.1.4 Reason for changing the type of wheelchair used

From a list of options respondents were asked to indicate which of those had influenced the decision to change the type of wheelchair used. Multiple responses were possible in this section and the result is presented in Figure 20.

Data for the option of loading the wheelchair in/out of the car was not available for 1991-97.

'N' is the number of respondents who have changed the type of wheelchair used at any time between discharge and the time of the survey.

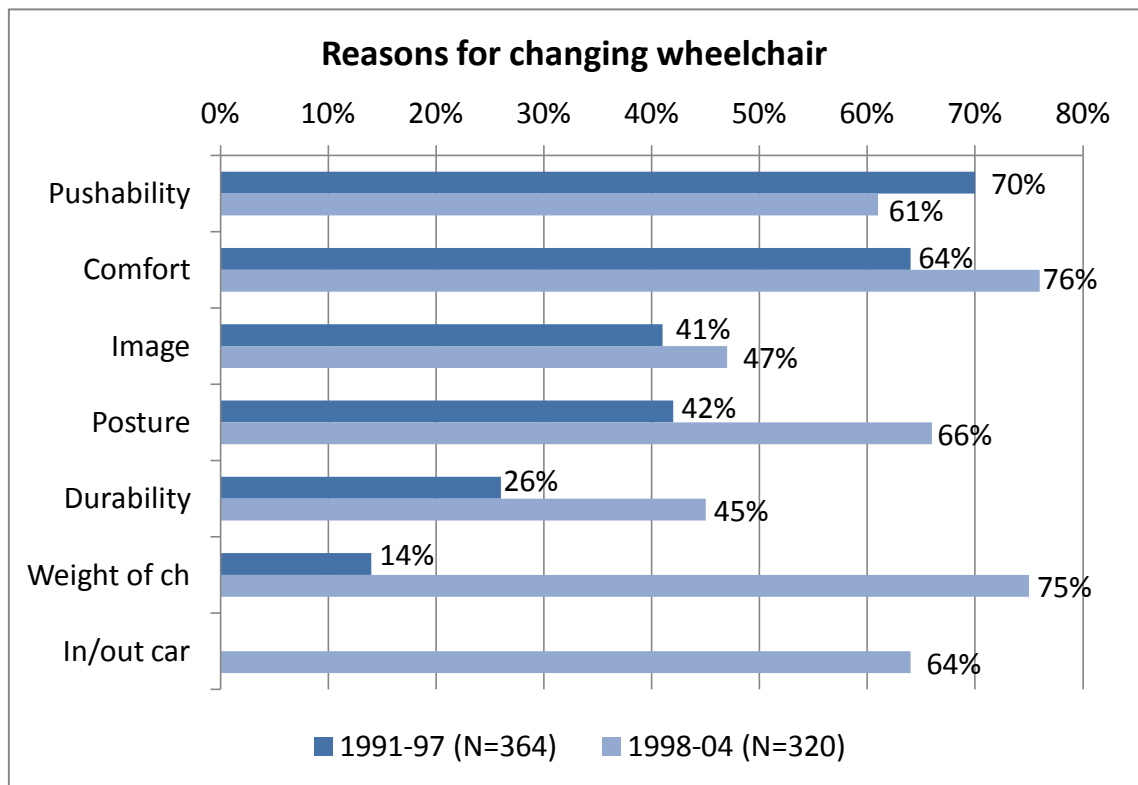


Figure 20 Reasons for changing type of wheelchair used.

4.1.5 Sources of funding for wheelchairs

Funding sources for the manual wheelchairs supplied as first, long-term provision (not interim) are presented in Figure 21 and for the wheelchairs used at the time of the surveys in Figure 22.

The partnership voucher option was only used for 4% and 7% of funding for 'first' and 'present' wheelchairs respectively; for ease of analysis partnership and independent voucher options were combined as funding source.

As the use of a voucher is not generally recommended for the first wheelchair for an inexperienced user, further analysis was carried out to determine if the wheelchairs funded by a voucher were changed within the lifetime of a voucher, i.e. 3-5 years. This showed that 40% of the wheelchairs funded by a voucher were changed within 3 years of discharge; 16% were changed within one year with a further 24% within 1-3 years of discharge.

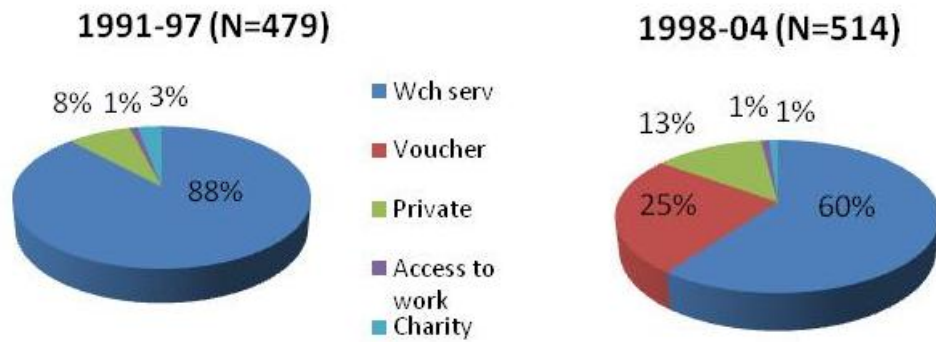


Figure 21 Funding sources for 'first' wheelchair. Voucher not available for 1991-97 period. 'Access to work' is a scheme funded by the government which will help fund equipment that will enable an individual to stay in work.

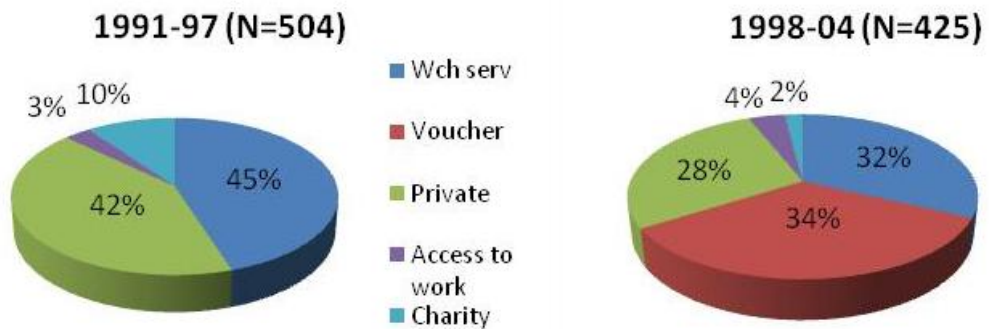


Figure 22 Funding sources for 'present' wheelchair. Voucher not available for 1991-97 period. 'Access to work' is a scheme funded by the government which will help fund equipment that will enable an individual to stay in work.

Figure 23 and Figure 24 illustrate the variance in the types of wheelchairs provided as first and present wheelchairs by the main sources of funding: Wheelchair Service outright, private outright and the Voucher Scheme (1998-2004 only).

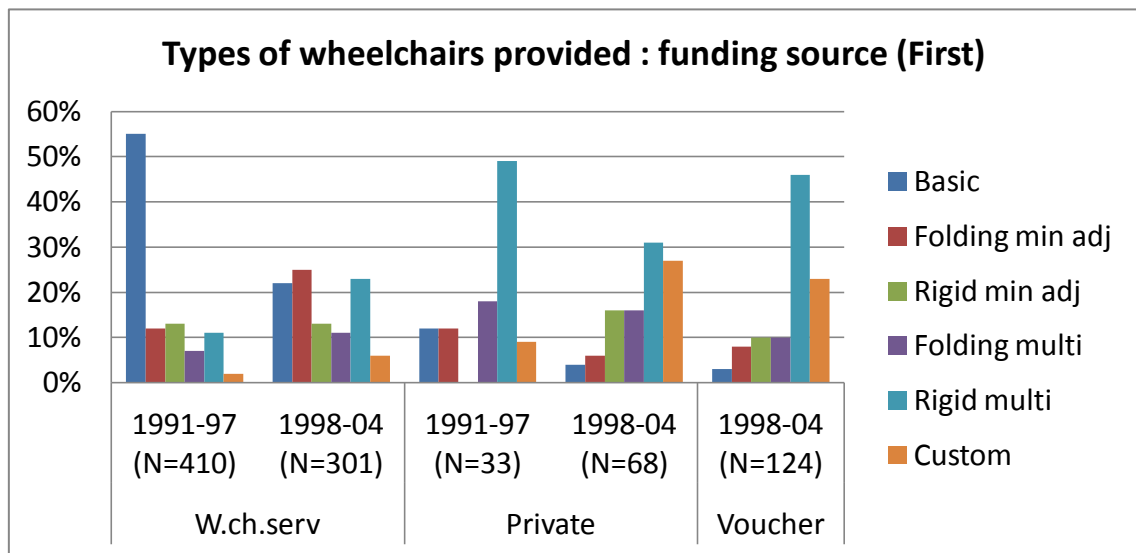


Figure 23 Types of wheelchairs provided analysed by source of funding for first wheelchair.

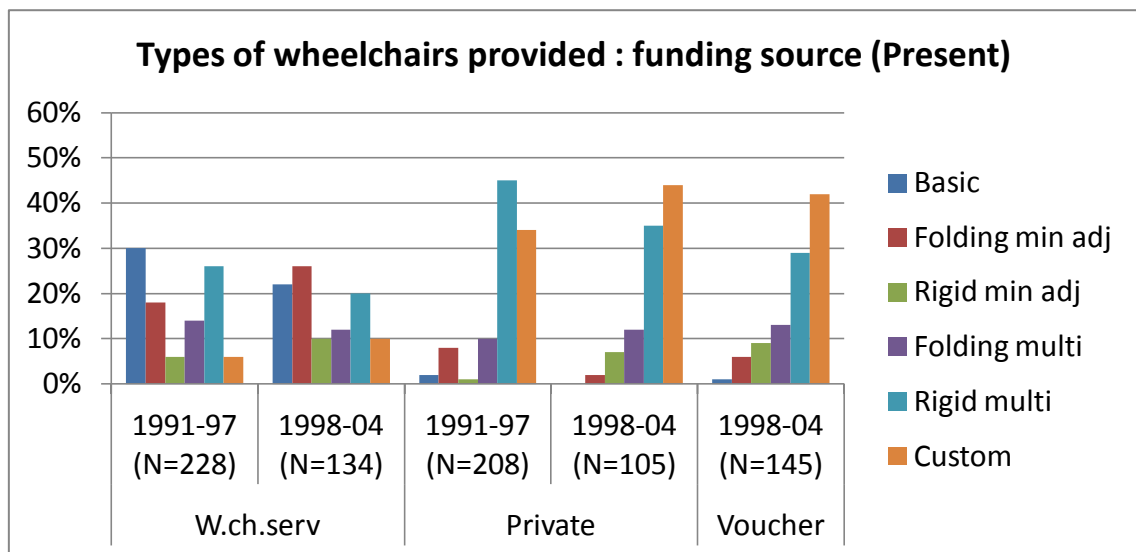


Figure 24 Types of wheelchairs provided analysed by source of funding for present wheelchair.

Not all the respondents using a voucher completed the section relating to the value of the voucher and the cost of the wheelchair for which the voucher was used. The ranges and averages for the value of the vouchers issued and the personal contribution are illustrated in Table 3. The number of cases, where the vouchers covered the cost of the wheelchair in full and therefore no personal contribution was required, is also included.

Table 3 Range and average value of vouchers and personal contribution for first and present wheelchairs.

	'First' (N= 135)	'Present' (N= 163)
Voucher – range – mean	£ 50 - £ 3457 £ 1016	£ 300 - £ 3500 £ 1056
Contribution – range – mean	£ 58 - £ 3500 £ 1004	£ 150 - £ 3100 £ 1596
No contribution required	35 (26%)	75 (48%)

4.1.6 User satisfaction

Participants in the 1998-2004 were asked to score their satisfaction with their first long-term provision and with the wheelchair they were using at the time of the survey. The results are presented in Figure 25.

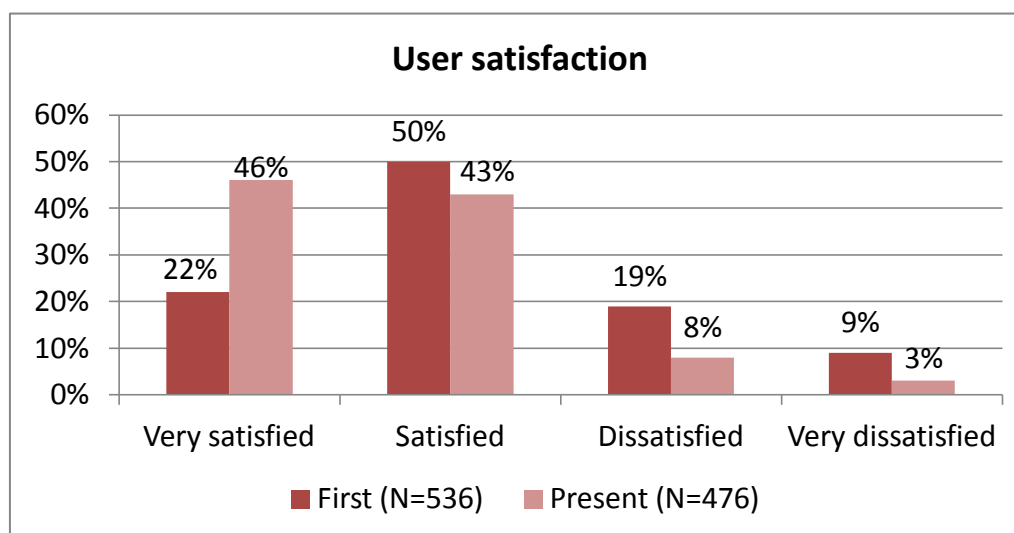


Figure 25 User satisfaction with 'first' and 'present' wheelchairs.

The difference in satisfaction with first and present wheelchairs was analysed, using the Wilcoxon signed-rank test and was found to be statistically significant ($p < 0.001$).

4.1.7 Adjustment of wheelchair

Of the 368 participants in the 1998-2004 survey who indicated that they had been supplied with a wheelchair with an adjustable axleplate, 312 (88%) said

that it had been adjusted on delivery. The adjustment had primarily been carried out by the dealer (48%), the Wheelchair Service (24%) and the spinal therapist (10%). In a further 11% the user had been involved in the adjustment in conjunction with somebody else (friend, family, dealer, Wheelchair Service or SCIC). The remainder were by a combination of all of the above.

Of the wheelchairs with rear axle adjustability funded by the Wheelchair Service outright, 91% of the wheelchairs supplied as first long-term chair was adjusted mainly by dealer (37%), Wheelchair Service (33%) or SCIC (16%). The user was involved in a further 10% of adjustments. For wheelchairs supplied as present wheelchairs and funded by the Wheelchair Service, 87% were adjusted on delivery. Of these 62% were adjusted by the Wheelchair Service. Both dealer and SCIC therapist accounted for 13% of adjustments. The user was involved in a further 6% of the adjustments.

4.1.8 Assessment

Although results for assessment were in the publication of the 1991-97 survey, this data was no longer available for analysis for the sample for England only.

Hence, the results presented here are from the 1998-2004 survey only.

When asked to indicate who had been involved in the assessment of the first and present wheelchairs, participants could indicate more than one from a list of options. The combination of professionals involved in the assessments is illustrated in Table 4.

Table 4 The professionals involved in the assessment for the first long-term and present wheelchairs (1998-2004 survey only).

Assessed by	First (N= 512)	Present (N=404)
SCIC therapist	34%	7%
Wheelchair Service therapist	13%	20%
Dealer/company representative	11%	45%
SCIC + Wheelchair Service	15%	5%
SCIC + Wheelchair Service + dealer	8%	2%
SCIC + dealer	13%	5%
Wheelchair Service + dealer	6%	16%

This concludes the presentation of the results for the national wheelchair provision surveys.

4.2 Propulsion Biomechanics

This section presents the results from the study investigating changes in propulsion biomechanics in a small cohort of people with new SCI.

The participants were tested using the SmartWheel at two time points: immediately prior to discharge referred to as 'T0' and at 6 months post-discharge, referred to as 'T6'. Not all the 19 participants recruited to the study were able to complete all tests at T0 or attend the follow up session at T6. Although 13 participants attended for testing at T6, full data sets are only available for 12 participants at T0 and T6.

A group of 10 experienced wheelchair users were also tested for comparison, using the same protocol.

4.2.1 Participant demographics

The demographics of both new and experienced wheelchair users are presented in Table 5.

Table 5 Demographics of new and experienced user groups.

	New (N=19)	Exp (N=10)
Age - mean	33 years	36 years
S.D.	10.2 years	10.2 years
Gender- male	16	8
female	3	2
Level - Cervical	1	3
Thoracic	16	7
Lumbar	2	0
AIS – A	14	9
AIS – B	1	1
AIS – C	4	0
Time since injury	< 2 years	2.75 – 14.25 years
Mean user weight	73.1 kg	
S.D.	13.3 kg	
Mean weight own chair (OC)	15.4 kg	
S.D.	2.0 kg	
Mean weight control chair (GPV)	13.8 kg	
S.D.	1.2 kg	

AIS refers to the ASIA Impairment Scale, a classification used for describing the degree of completeness of the SCI. For full definition of the different categories, see '[Abbreviations and Definitions](#)'.

No weight data was available for the experienced user group.

Based on the [classification of wheelchairs](#) used in the wheelchair provision surveys, the types of wheelchairs used by the new users ranged from basic (N=3) and minimally adjustable folding wheelchairs (N=2) to custom wheelchairs (N=2) with the majority having lightweight, multi-adjustable wheelchairs (N=12).

4.2.2 Whole group results

The overall results for the whole participant group, new and experienced users, are presented in Table 6 for the test on lino and in Table 7 for the test on the ramp. Results are given for the test in both own chair (OC) and the control chair (GPV) at discharge ('T0') and 6 months post discharge ('T6'). Mean values with standard deviation are given for the 4 variables chosen for analysis: velocity, stroke length, stroke frequency and peak resultant force (F_{res}).

Table 6 Mean and standard deviation for all test variables for new and experienced users on 'Lino'.

LINO								
	Velocity (m/sec)		Stroke Length (°)		Stroke frequency (Stroke/sec)		Peak F_{res} (N)	
New	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
T0 OC N=18	1.50	0.31	88.4	9.5	0.91	0.08	90.2	20.3
T6 OC N=13	1.54	0.15	91.8	9.1	0.80	0.26	107.69	30.3
T0GPV N=19	1.45	0.18	87.9	9.1	0.95	0.24	90.7	29.2
T6GPV N=13	1.57	0.15	107.7	10.0	0.79	0.22	100.3	22.9
Exp								
OC N=10	1.43	0.36	89.9	12.7	0.86	0.27	101.7	28.7
GPV N=10	1.41	0.26	88.6	13.0	0.84	0.21	97.7	30.3

Table 7 Mean and standard deviation for all variables for new and experienced users on 'Ramp'.

RAMP								
	Velocity (m/sec)		Stroke Length (°)		Stroke frequency (Stroke/sec)		Peak F _{res} (N)	
New	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
T0 OC N=18	0.61	0.15	84.5	11.6	0.89	0.1	117.0	19.0
T6 OC N=13	0.83	0.21	88.7	12.1	0.96	0.14	148.1	53.0
T0GPV N=19	0.59	0.12	85.1	12.4	0.88	0.09	114.0	32.5
T6GPV N=13	0.78	0.28	90.3	11.1	0.94	0.09	139.8	46.9
Exp								
OC N=10	0.83	0.49	87.4	18.2	1.01	0.40	129.1	28.2
GPV N=10	0.76	0.44	84.2	13.6	0.99	0.34	126.0	28.4

A velocity of 1.06 m/s is the recommended minimum velocity for safe and successful community participation. This is based on the average minimum time that it takes to cross a road (Cowan et al. 2008).

Figure 26 presents the velocity results for the new users at T0 and T6 and for experienced users at T0 in own chairs (OC).

The threshold level of 1.06 m/sec is marked with a horizontal line.

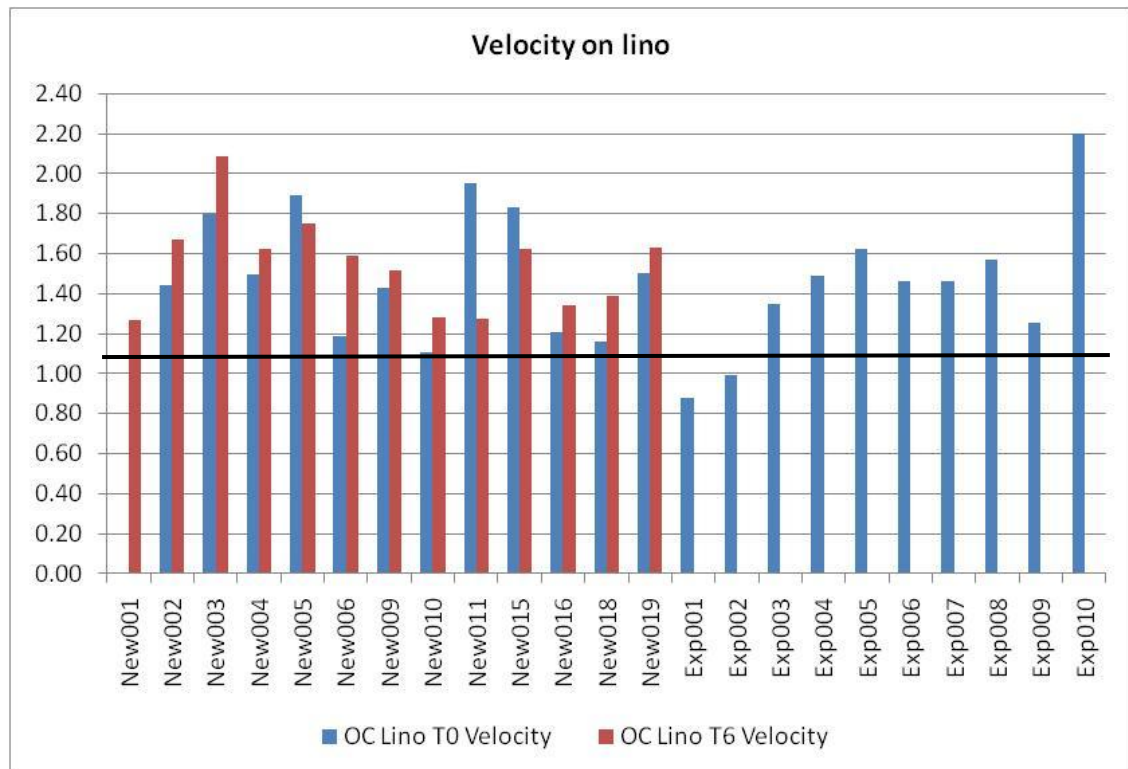


Figure 26 Velocity (m/sec) results on lino for new (N = 13) and experienced users (N = 10). Minimum threshold for safe community participation is marked with horizontal line. Velocity data was missing for 6 new users. Velocity data for subject New001 was missing for T6.

4.2.3 New users

For the purpose of investigating further the differences in propulsion over time in the new users, the results for T0 and T6 were analysed using paired t-test statistics. The 12 participants with full data sets for all variables at the two time points were used in this analysis.

The results for the tests on lino and ramp are presented in the following section for the variables velocity, stroke length, stroke frequency and Peak F_{res} . The mean, median, range and standard deviation are given for all results as well as the statistical significance for the paired t-test or Wilcoxon signed-ranks t-test analysis.

4.2.3.1 Velocity

The analysis presented in Table 8 compares the propulsion results for velocity on lino for the 12 participants in their own chair (OC) at T0 compared to T6 and in the control chair (GPV) at T0 compared to T6. The results for velocity difference on lino between T0 and T6 were found to be non-significant.

Table 8 Propulsion results for velocity on lino at T0 and T6 in OC and GPV for new users.

Velocity (m /sec)					
User ID	OC Lino T0	OC Lino T6	User ID	GPVLino T0	GPVLino T6
New002	1.44	1.67	New002	1.31	1.59
New003	1.80	2.09	New003	1.47	2.22
New004	1.49	1.63	New004	1.74	1.58
New005	1.89	1.75	New005	2.10	2.03
New006	1.19	1.59	New006	1.03	1.51
New009	1.43	1.52	New009	1.65	1.81
New010	1.11	1.28	New010	1.29	1.03
New011	1.95	1.27	New011	1.20	1.23
New015	1.83	1.62	New015	1.59	1.64
New016	1.21	1.34	New016	1.24	1.45
New018	1.16	1.39	New018	1.31	1.64
New019	1.50	1.63	New019	1.58	1.35
Mean	1.50	1.57	Mean	1.46	1.59
Median	1.47	1.61	Median	1.39	1.58
Range	1.11-1.95	1.27-2.09	Range	1.03-2.1	1.03-2.22
SD	0.31	0.15	SD	0.18	0.15
Paired t-test	$p = 0.4473$		Paired t-test	$p = 0.1623$	

The results for velocity on the ramp are presented in Table 9.

Table 9 Propulsion results for velocity on ramp at T0 and T6 in OC and GPV for new users.

Velocity (m /sec)					
User ID	OCRamp T0	OCRamp T6	User ID	GPVRamp T0	GPVRamp T6
New002	0.40	0.56	New002	0.44	0.46
New003	0.71	1.08	New003	0.48	0.99
New004	0.58	0.45	New004	0.58	0.54
New005	0.97	1.27	New005	0.83	1.31
New006	0.10	0.56	New006	0.11	0.49
New009	0.81	1.06	New009	0.78	0.97
New010	0.60	1.01	New010	0.66	0.95
New011	0.71	1.20	New011	0.78	1.12
New015	0.65	0.93	New015	0.75	0.75
New016	0.42	0.59	New016	0.57	0.51
New018	0.60	0.78	New018	0.64	0.62
New019	0.79	1.10	New019	0.84	1.16
Mean	0.61	0.88	Mean	0.62	0.82
Median	0.62	0.97	Median	0.65	0.85
Range	0.1–0.97	0.45–1.27	Range	0.11-0.84	0.46-1.31
SD	0.15	0.21	SD	0.12	0.28
<i>Paired t-test</i>	<i>p = 0.0001</i>		<i>Paired t-test</i>	<i>p = 0.008</i>	

The paired t-test analysis of the velocity results on the ramp at T0 compared to T6 shows highly significant difference for both own chair ($p = 0.0001$) and for the GPV ($p = 0.008$).

4.2.3.2 Stroke length

The analysis presented in Table 10 compares the propulsion results for stroke length on lino for the 12 participants in their own chair (OC) at T0 compared to T6 and in the GPV at T0 compared to T6. Figures have been rounded to whole numbers.

The result for stroke length difference on lino between T0 and T6 was found not to be significant for the result in own chair and slightly significant for the test in the GPV ($p= 0.045$).

Table 10 Propulsion results for stroke length on lino at T0 and T6 in OC and GPV for new users.

Stroke length (arc °)					
	OCLino			GPVLino	
User ID	T0	T6	User ID	T0	T6
New002	81	97	New002	74	105
New003	84	82	New003	78	87
New004	85	94	New004	77	94
New005	105	118	New005	106	122
New006	51	70	New006	46	167
New009	104	111	New009	120	198
New010	100	105	New010	100	99
New011	113	97	New011	98	101
New015	80	89	New015	86	87
New016	69	79	New016	75	75
New018	80	97	New018	101	99
New019	94	78	New019	93	83
Mean	87	93	Mean	88	110
Median	84	95	Median	90	99
Range	51 - 113	70 - 118	Range	46 - 120	75 - 198
SD	10.48	9.01	SD	11.22	9.96
<i>Paired t-test</i>	$p = 0.1103$		<i>Wilcoxon signed-ranks t-test</i>	$p = 0.045$	

The results for stroke length on the ramp are presented in Table 11.

Table 11 Propulsion results for stroke length on the ramp at T0 and T6 in OC and GPV for new users.

Stroke length (arc °)					
User ID	OCRamp		User ID	GPVRamp	
	T0	T6		T0	T6
New002	69	79	New002	74	98
New003	73	82	New003	100	68
New004	84	88	New004	85	87
New005	97	106	New005	109	111
New006	58	68	New006	54	61
New009	105	120	New009	101	107
New010	89	105	New010	78	95
New011	103	108	New011	96	111
New015	89	91	New015	88	103
New016	81	84	New016	72	78
New018	72	76	New018	90	91
New019	85	63	New019	92	82
Mean	84	89	Mean	87	91
Median	85	86	Median	89	93
Range	58 - 105	63 - 120	Range	54 - 109	61 - 111
SD	7.46	12.14	SD	9.15	11.11
<i>Paired t-test</i>	<i>p = 0.0783</i>		<i>Paired t-test</i>	<i>p = 0.3215</i>	

The propulsion results for stroke length difference on the ramp between T0 and T6 were found to be non-significant.

4.2.3.3 Stroke frequency

The analysis presented in Table 12 compares the propulsion results for stroke frequency on lino for the 12 participants in their own chair (OC) at T0 compared to T6 and in the GPV at T0 compared to T6. The results were found to be non-significant for both own chair and GPV.

Table 12 Propulsion results for stroke frequency on lino at T0 and T6 in OC and GPV for new users.

Stroke frequency (pushes / sec)					
User ID	OCLino T0	OCLino T6	User ID	GPVLino T0	GPVLino T6
New002	0.86	0.94	New002	0.68	0.65
New003	0.99	0.83	New003	1.05	0.76
New004	1.20	0.69	New004	1.26	0.66
New005	1.07	0.54	New005	1.14	0.35
New006	0.97	0.96	New006	0.99	0.88
New009	1.02	0.84	New009	0.89	1.02
New010	0.63	0.62	New010	0.74	0.59
New011	0.95	0.86	New011	1.10	0.74
New015	0.82	0.89	New015	1.18	0.87
New016	0.89	1.01	New016	0.63	1.12
New018	0.70	0.41	New018	0.74	0.59
New019	0.75	0.82	New019	0.82	0.84
Mean	0.91	0.79	Mean	0.94	0.76
Median	0.92	0.84	Median	0.94	0.75
Range	0.63 – 1.2	0.41 – 1.01	Range	0.63 – 1.26	0.35 – 1.12
SD	0.08	0.26	SD	0.24	0.22
<i>Paired t-test</i>	<i>p = 0.091</i>		<i>Paired t-test</i>	<i>p = 0.0889</i>	

The results for stroke frequency on the ramp are presented in Table 13.

Table 13 Propulsion results for stroke frequency on the ramp for T0 and T6 in OC and GPV for new users.

Stroke frequency (pushes / sec)					
User ID	OC RampT0	OC RampT6	User ID	GPV RampT0	GPV RampT6
New002	0.66	0.91	New002	0.70	0.67
New003	0.86	1.04	New003	0.76	1.06
New004	1.08	0.87	New004	1.05	0.93
New005	1.03	0.87	New005	1.00	1.02
New006	0.61	1.01	New006	0.61	0.93
New009	0.90	1.04	New009	0.85	1.02
New010	0.95	1.05	New010	1.07	1.04
New011	0.91	0.99	New011	1.01	1.01
New015	1.02	1.20	New015	1.12	1.03
New016	0.79	0.88	New016	0.95	0.87
New018	0.98	1.12	New018	0.92	0.90
New019	0.91	1.03	New019	0.95	1.06
Mean	0.89	1.00	Mean	0.92	0.96
Median	0.91	1.02	Median	0.95	1.02
Range	0.61 – 1.08	0.87 – 1.2	Range	0.61 – 1.12	0.67 – 1.06
SD	0.10	0.14	SD	0.09	0.09
<i>Paired t-test</i>	$p = 0.0385$		<i>Wilcoxon Signed-ranks t-test</i>	$p = 0.624$	

The difference in stroke frequency on the ramp between T0 and T6 was found to be statistically significant in own chair ($p = 0.0385$) but not in the GPV.

4.2.3.4 Peak resultant force (Peak F_{res})

The analysis presented in Table 14 compares the propulsion results for Peak F_{res} on lino for the 12 participants in their own chair (OC) at T0 compared to T6 and in the GPV at T0 compared to T6. Figures have been rounded to whole numbers.

The result for Peak F_{res} in own chair on lino showed statistically significant difference between T0 and T6 ($p = 0.0033$).

Table 14 Propulsion results for Peak F_{res} on lino for T0 and T6 in OC and GPV for new users.

Peak F_{res} (N)					
User ID	OCLino		User ID	GPVLino	
	T0	T6		T0	T6
New002	103	143	New002	123	131
New003	86	99	New003	52	104
New004	95	131	New004	120	97
New005	79	131	New005	91	146
New006	89	119	New006	123	54
New009	60	61	New009	71	62
New010	52	97	New010	51	105
New011	104	76	New011	88	84
New015	130	148	New015	103	141
New016	88	122	New016	90	127
New018	66	77	New018	47	94
New019	92	131	New019	84	97
Mean	87	111	Mean	87	104
Median	89	121	Median	89	100
Range	52 - 130	61 - 148	Range	47 - 123	54 - 146
SD	21.17	28.68	SD	27.60	28.93
Paired t-test	$p = 0.0033$		Paired t-test	$p = 0.1568$	

The results for Peak F_{res} on the ramp are presented in Table 15.

Table 15 Propulsion results for Peak F_{res} on the ramp for T0 and T6 in OC and GPV for new users.

Peak F_{res} (N)					
User ID	OCRamp		User ID	GPVRamp	
	T0	T6		T0	T6
New002	126	153	New002	108	156
New003	87	154	New003	83	112
New004	117	150	New004	125	133
New005	130	146	New005	126	157
New006	131	114	New006	158	112
New009	89	84	New009	85	118
New010	95	197	New010	84	181
New011	99	162	New011	118	150
New015	144	180	New015	129	167
New016	119	162	New016	106	137
New018	135	101	New018	77	100
New019	96	229	New019	151	211
Mean	114	153	Mean	113	144
Median	118	154	Median	113	143
Range	87 - 144	84 - 229	Range	77 - 158	100 - 211
SD	20.99	53.00	SD	31.77	46.86
<i>Paired t-test</i>	<i>p = 0.0172</i>		<i>Paired t-test</i>	<i>p = 0.0066</i>	

The paired t-test analysis indicate that the results for Peak F_{res} at T0 compared to T6 on the ramp were found to be significantly different for both own chair ($p=0.0172$) and the GPV ($p=0.0066$).

The results for Peak F_{res} normalised for user weight, as recommended by the SmartWheel User Group, as well as normalised for total weight (user plus wheelchair) are presented for new users in own chair on lino in Table 16 and for the ramp in Table 17.

None of the weight normalised F_{res} results were found to be statistically significant.

Table 16 Peak F_{res} for new user on lino in OC. For weight normalisation of the Peak F_{res} results, user and wheelchair mass (kg) has been converted to weight (N).

Peak F_{res} (N) OC Lino									
Number	User Weight (N) T0	User Weight (N) T6	Own Chair weight (N)	Peak F_{res} (N) T0	Peak F_{res} (N) T6	Peak F_{res} /User Weight T0	Peak F_{res} /User Weight T6	Peak F_{res} /Weight of user + chair T0	Peak F_{res} /Weight of user + chair T6
New002	563.73	772.33	178.54	103.09	143.43	0.18	0.19	0.14	0.15
New003	516.23	646.93	131.45	85.62	98.81	0.17	0.15	0.13	0.13
New004	792.88	971.66	176.58	95.21	131.37	0.12	0.14	0.10	0.11
New005	434.79	610.60	173.64	78.70	130.61	0.18	0.21	0.13	0.17
New006	564.37	725.56	158.92	89.48	119.32	0.16	0.16	0.12	0.13
New009	375.72	522.17	137.44	60.05	61.12	0.16	0.12	0.12	0.09
New010	558.62	702.27	143.23	52.22	96.93	0.09	0.14	0.07	0.11
New011	901.54	901.54	154.02	104.07	75.62	0.12	0.08	0.10	0.07
New015	852.40	852.40	155.98	129.61	147.84	0.15	0.17	0.13	0.15
New016	688.97	821.72	130.47	88.45	122.19	0.13	0.15	0.11	0.13
New018	535.92	689.25	156.96	65.72	76.85	0.12	0.11	0.09	0.09
New019	658.54	817.75	154.02	92.41	130.81	0.14	0.16	0.11	0.13
Mean	620.31	752.85	154.27	87.05	111.24	0.14	0.15	0.11	0.12
Median				88.97	120.76	0.15	0.15	0.12	0.13
Range				52-130	61-148				
SD				21.17	28.68	0.03	0.04	0.02	0.03
Paired t-test				0.0033		0.4899		0.1447	

Table 17 Peak F_{res} for new users on the ramp in OC. For weight normalisation of the Peak F_{res} results, user and wheelchair mass (kg) has been converted to mass (N).

Peak F_{res} (N) OC Ramp									
Number	User Weight (N) T0	User Weight (N) T6	Own Chair Weight (N)	Peak F_{res} (N) T0	Peak F_{res} (N) T6	Peak F_{res} /User Weight T0	Peak F_{res} /User Weight T6	Peak F_{res} /Weight of user + chair T0	Peak F_{res} /Weight of user + chair T6
New002	563.73	772.33	178.54	125.9	153.3	0.22	0.20	0.17	0.16
New003	516.23	646.93	131.45	87.3	154.2	0.17	0.24	0.13	0.20
New004	792.88	971.66	176.58	117.3	150.3	0.15	0.15	0.12	0.13
New005	434.79	610.60	173.64	130.1	146.4	0.30	0.24	0.21	0.19
New006	564.37	725.56	158.92	131.1	114.1	0.23	0.16	0.18	0.13
New009	375.72	522.17	137.44	88.8	83.9	0.24	0.16	0.17	0.13
New010	558.62	702.27	143.23	94.8	196.8	0.17	0.28	0.14	0.23
New011	901.54	901.54	154.02	98.8	161.9	0.11	0.18	0.09	0.15
New015	852.40	852.40	155.98	143.9	179.8	0.17	0.21	0.14	0.18
New016	688.97	821.72	130.47	118.7	161.5	0.17	0.20	0.14	0.17
New018	535.92	689.25	156.96	134.6	101.1	0.25	0.15	0.19	0.12
New019	658.54	817.75	154.02	95.9	229.4	0.15	0.28	0.12	0.24
Mean	620.31	752.85	154.27	113.9	152.7	0.19	0.20	0.15	0.17
Median				118.0	153.8	0.17	0.20	0.14	0.17
Range				87-144	84-229				
SD				19.8	40.1	0.05	0.05	0.04	0.04
Paired t-test				0.0172		0.6719		0.3625	

This concludes the results section relating to the analysis of propulsion biomechanics for new users over time in own chair and GPV.

4.2.4 New users versus experienced users

The following section presents the results for the comparison of new users with experienced users. In order to be able to analyse the sample using independent t-test statistics, the new user group had to be matched in numbers to the 10 experienced users. The groups were matched according to AIS classification and then level and gender. The demographics of the two groups are presented in Table 18.

Table 18 Demographics of new and experienced sample used in the new/experienced analysis.

	New (N=10)	Exp (N=10)
Age - mean	34.6 years	35.7 years
S.D.	11.5 years	10.2 years
Gender- male	8	8
female	2	2
Level - Cervical	0	3
Thoracic	10	7
Lumbar	0	0
AIS – A	9	9
AIS – B	0	1
AIS – C	1	0

The following section presents the propulsion results for all the variables on lino and ramp, in OC and GPV. The experienced users were only tested on one occasion. The test results from T0 were used for the new users as this was most likely to demonstrate the greatest difference in performance compared to the experienced users. Independent t-test analysis was used to test for statistical significance of differences between the two groups, new and experienced users.

4.2.4.1 Velocity

The results for the analysis of velocity on lino and ramp, for OC and GPV are presented in Table 19. Independent t-test statistics revealed no statistically significant difference between new and experienced users for any of the velocity results.

Table 19 Propulsion results for velocity on lino and ramp in OC and GPV for new and experienced users.

Velocity (m/sec)								
	OC Lino		GPV Lino		OC Ramp		GPV Ramp	
	Exp	New T0	Exp	New T0	Exp	New T0	Exp	New T0
	0.88	1.44	0.95	1.31	0.26	0.40	0.25	0.44
	0.99	1.80	1.20	1.47	0.18	0.71	0.19	0.48
	1.35	1.49	1.42	1.74	0.53	0.58	0.54	0.58
	1.49	1.19	1.56	1.03	0.77	0.10	0.82	0.11
	1.63	1.43	1.59	1.65	0.80	0.81	0.80	0.78
	1.46	1.95	1.35	1.20	1.48	0.71	1.34	0.78
	1.46	1.83	1.41	1.59	0.60	0.65	0.57	0.75
	1.57	1.21	1.53	1.24	0.84	0.42	0.66	0.57
	1.26	1.16	1.18	1.31	1.07	0.60	0.87	0.64
	2.20	1.50	1.90	1.58	1.74	0.79	1.58	0.84
Mean	1.43	1.50	1.41	1.41	0.83	0.58	0.76	0.60
Median	1.46	1.47	1.41	1.39	0.78	0.62	0.73	0.61
SD	0.36	0.28	0.26	0.23	0.49	0.22	0.44	0.22
t-test	p=0.6473		p=0.9829		p=0.1277		p=0.2103	

4.2.4.2 Stroke length and frequency

The results for stroke length on lino and ramp in OC and GPV are presented in Table 20 for new and in Table 21 for experienced users. Figures have been rounded to whole numbers. The results for stroke frequency on lino and ramp in OC and GPV are presented in for new and experienced users.

Independent t-test statistics revealed no statistically significant difference for stroke length or stroke frequency between new and experienced users.

Table 20 Propulsion results for stroke length on lino and ramp in OC and GPV for new and experienced users.

Stroke length (arc °)								
	OC Lino		GPV Lino		OC Ramp		GPV Ramp	
	Exp	New T0	Exp	New T0	Exp	New T0	Exp	New T0
	92	81	96	74	80	69	89	74
	70	84	75	78	56	73	66	100
	68	85	66	77	72	84	68	85
	95	51	86	46	90	58	91	54
	81	104	86	120	82	105	76	101
	94	113	93	98	108	103	97	96
	93	80	91	86	93	89	77	88
	97	69	87	75	84	81	81	72
	103	80	116	101	123	72	110	90
	105	94	90	93	85	85	87	92
Mean	90	84	89	85	87	82	84	85
Median	94	83	89	82	85	83	84	89
SD	12.74	17.32	13.03	19.92	18.23	14.78	13.58	14.62
<i>t-test</i>	<i>p=0.4492</i>		<i>p=0.5760</i>		<i>p=0.4587</i>		<i>p=0.8873</i>	

Table 21 Propulsion results for stroke frequency on lino and ramp in OC and GPV for new and experienced users.

Stroke frequency (pushes / sec)								
	OC Lino		GPV Lino		OC Ramp		GPV Ramp	
	Exp	New T0	Exp	New T0	Exp	New T0	Exp	New T0
	0.88	0.86	0.79	0.68	0.53	0.66	0.61	0.70
	0.91	0.99	0.90	1.05	0.52	0.86	0.49	0.76
	1.16	1.20	0.92	1.26	0.94	1.08	1.00	1.05
	0.99	0.97	1.02	0.99	1.10	0.61	1.14	0.61
	1.25	1.02	1.18	0.89	1.14	0.90	1.16	0.85
	0.93	0.95	0.86	1.10	1.27	0.91	1.29	1.01
	0.74	0.82	0.76	1.18	0.80	1.02	0.88	1.12
	0.62	0.89	0.80	0.63	1.06	0.79	0.91	0.95
	0.30	0.70	0.37	0.74	0.83	0.98	0.77	0.92
	0.86	0.75	0.81	0.82	1.91	0.91	1.67	0.95
Mean	0.86	0.92	0.84	0.93	1.01	0.87	0.99	0.89
Median	0.89	0.92	0.83	0.94	1.00	0.90	0.96	0.93
SD	0.27	0.14	0.21	0.22	0.40	0.15	0.34	0.16
<i>t-test</i>	<i>p=0.3763</i>		<i>p=0.2629</i>		<i>p=0.313</i>		<i>p=0.3728</i>	

4.2.4.3 Peak F_{res}

The results for Peak F_{res} on lino and ramp in OC and GPV are presented in Table 22 for new and experienced users.

Figures have been rounded to whole numbers. Independent t-test statistics revealed no statistically significant difference for Peak F_{res} between new and experienced users.

Table 22 Propulsion results for Peak F_{res} on lino and ramp in OC and GPV for new and experienced users.

Peak F_{res} (N)								
	OC Lino		GPV Lino		OC Ramp		GPV Ramp	
	Exp	New T0	Exp	New T0	Exp	New T0	Exp	New T0
	58	103	57	123	95	126	95	108
	84	86	86	52	100	87	114	83
	111	95	106	120	133	117	126	125
	116	89	87	123	144	131	119	158
	100	60	93	71	107	89	111	85
	100	104	99	88	157	99	144	118
	69	130	78	103	100	144	86	129
	95	88	97	90	126	119	130	106
	125	66	100	47	155	135	152	77
	159	92	174	84	175	96	184	151
Mean	102	91	98	90	129	114	126	114
Median	100	91	95	89	130	118	123	113
SD	28.72	19.61	30.25	27.87	28.19	20.24	28.42	27.72
<i>t-test</i>	<i>p=0.4463</i>		<i>p=0.6031</i>		<i>p=0.2254</i>		<i>p=0.3182</i>	

As no weight data was available for the experienced user no weight normalised conversion could be applied.

4.2.5 Propulsion results for new users analysed by type of wheelchair

To investigate further the result from the first wheelchair provision survey linking early change of wheelchair to the type of wheelchair used and 'pushability', the propulsion parameters were analysed according to the [wheelchair classification](#) used in the wheelchair provision surveys (Table 23).

Table 23 Mean values and standard deviation for all propulsion test parameters for new users in own chair analysed according to wheelchair classification used in provision surveys.

	Velocity (m/sec)				Stroke Length (°)				Stroke Frequency (Strokes/sec)				Peak F _{res} weight normalised			
Lino	T0		T6		T0		T6		T0		T6		T0		T6	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Basic (N=1)*	1.11		1.28		99.64		105.15		0.63		0.62		0.07		0.11	
Min adj folding (N=2)	1.31	0.18	1.63	0.06	66.17	21.48	83.32	18.98	0.92	0.08	0.95	0.01	0.14	0.02	0.18	0.02
Multi-adj Folding (N=1)	1.49		1.63		84.79		93.89		1.20		0.69		0.10		0.14	
Multi-adj Rigid (N=6)	1.63	0.29	1.60	0.30	94.88	16.23	94.16	17.62	0.95	0.12	0.82	0.16	0.12	0.01	0.15	0.05
Custom (N=2)	1.50	0.48	1.51	0.16	80.31	0.08	92.96	5.22	0.76	0.08	0.65	0.34	0.13	0.04	0.14	0.04
Ramp	T0		T6		T0		T6		T0		T6		T0		T6	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Basic (N=1)*	0.60		1.01		89.06		104.85		0.95		1.05		0.14		0.28	
Min adj folding (N=2)	0.25	0.21	0.56	0.00	63.58	7.75	73.43	7.73	0.63	0.03	0.96	0.07	0.18	0.00	0.18	0.03
Multi-adj Folding (N=1)	0.58		0.45		84.44		88.10		1.08		0.87		0.12		0.15	
Multi-adj Rigid (N=6)	0.73	0.18	1.05	0.24	90.66	12.99	93.88	21.13	0.90	0.08	0.98	0.08	0.15	0.04	0.22	0.04
Custom (N=2)	0.62	0.04	0.85	0.10	80.46	12.44	83.88	10.78	1.00	0.03	1.16	0.05	0.18	0.01	0.18	0.04

* The only user with a basic wheelchair (Quickie Breezy) was an individual with a SCI at the level of L2, AIS 'C'. A person with that level of SCI would be unlikely to be a full-time manual wheelchair user and is likely to be ambulating for part of the time.

A summary of the difference (absolute and %) in the mean value and the difference in the standard deviation for each propulsion parameter between the test at T0 and T6 is presented in Table 24.

Table 24 Summary table of the difference in mean and standard deviation (SD) for all propulsion parameters at T0 and T6 for each wheelchair group.

Lino	Velocity			Stroke Length			Stroke Frequency			Peak F _{res} Weight Norm.		
	Mean diff T0/T6	% Diff	SD diff T0/T6	Mean diff T0/T6	% Diff	SD diff T0/T6	Mean diff T0/T6	% Diff	SD diff T0/T6	Mean diff T0/T6	% Diff	SD diff T0/T6
<i>Basic (N=1)</i>	0.17	13.3%		5.51	5.2%		-0.01	-1.6%		0.04	36.4%	
Min adj folding (N=2)	0.32	19.6%	0.12	17.15	20.6%	2.50	0.03	3.2%	0.07	0.04	22.2%	0.00
<i>Multi-adj Folding (N=1)</i>	0.14	8.5%		9.1	9.7%		-0.51	-73.9%		0.04	28.6%	
Multi-adj Rigid (N=6)	-0.03	-1.9%	-0.01	-0.72	-0.8%	-1.39	-0.13	-15.9%	-0.04	0.03	20.0%	0.04
Custom (N=2)	0.01	0.6%	0.32	12.65	13.6%	-5.14	-0.11	-16.9%	-0.26	0.01	7.1%	0.00
Ramp	Velocity			Stroke Length			Stroke Frequency			Peak F _{res} Weight Norm.		
	Mean diff T0/T6	% Diff	SD diff T0/T6	Mean diff T0/T6	% Diff	SD diff T0/T6	Mean diff T0/T6	% Diff	SD diff T0/T6	Mean diff T0/T6	% Diff	SD diff T0/T6
<i>Basic (N=1)</i>	0.41	40.6%	0.00	15.79	15.1%		0.10	9.5%		0.14	50.0%	
Min adj folding (N=2)	0.31	55.4%	0.21	9.86	13.4%	0.02	0.33	34.4%	-0.04	0.00	0.00%	-0.03
<i>Multi-adj Folding (N=1)</i>	-0.13	-0.3%		3.66	4.1%		-0.21	24.1%		0.03	20.0%	
Multi-adj Rigid (N=6)	0.32	30.5%	-0.06	3.22	3.4%	-8.14	0.08	8.2%	0.00	0.07	31.8%	0.00
Custom (N=2)	0.23	27.1%	-0.06	3.42	4.1%	1.66	0.16	13.7%	-0.02	0.00	0.00%	-0.03

A positive value in the mean difference represents an increase in the mean value from T0 to T6; a negative value represents a decrease in the value from T0 to T6.

For the difference in SD, a positive value represents a decrease in the SD from T0 to T6 and a negative value represents an increase in the SD from T0 to T6.

These outcomes are discussed in [Chapter 5.2.6](#).

This concludes the results section for the propulsion biomechanics aspects of this thesis.

4.3 Shoulder Pain

This section presents the results from the 705 full-time, manual wheelchair users who returned a completed WUSPI and survey questionnaire (Chapter 4.1). The study participants were recruited from the SCICs in England, Scotland and Northern Ireland.

The information gathered from the WUSPI will be presented separately as well as in the context of the information the participants gave as part of the wheelchair provision survey.

As not all respondents completed all sections, 'N' will vary and will be given for each section presented.

4.3.1 Demographics

The demographic characteristics of the study population are presented in Table 25. For the purpose of this aspect of the thesis the levels of injury have been collapsed into just two groups: tetraplegics and paraplegics.

Table 25 Demographics of study population

Age (N= 703)				Gender (N= 482)		Level of injury (N= 642)	
0-19	20-39	40-59	>60	Male	Female	Tetraplegic	Paraplegic
2%	39%	36%	23%	75%	25%	27%	73%

4.3.2 Prevalence of pain

The presence of pain was defined as the respondent reporting pain of > 1 cm on the 10cm VAS in at least one WUSPI variable. The overall prevalence of pain for the whole sample was 66%. The prevalence of pain according to age groups, gender and level of injury is presented in Figure 27.

Chi-square statistics were used to analyse the difference in the prevalence of pain according to age, gender and level of injury. For this purpose age was collapsed into '< 40 years' and '> 40 years'. The difference in the prevalence of

pain was found to be statistically significant for age ($p=0.036$) and level ($p=0.007$). The difference in prevalence of pain was not found to be statistically significant for gender.

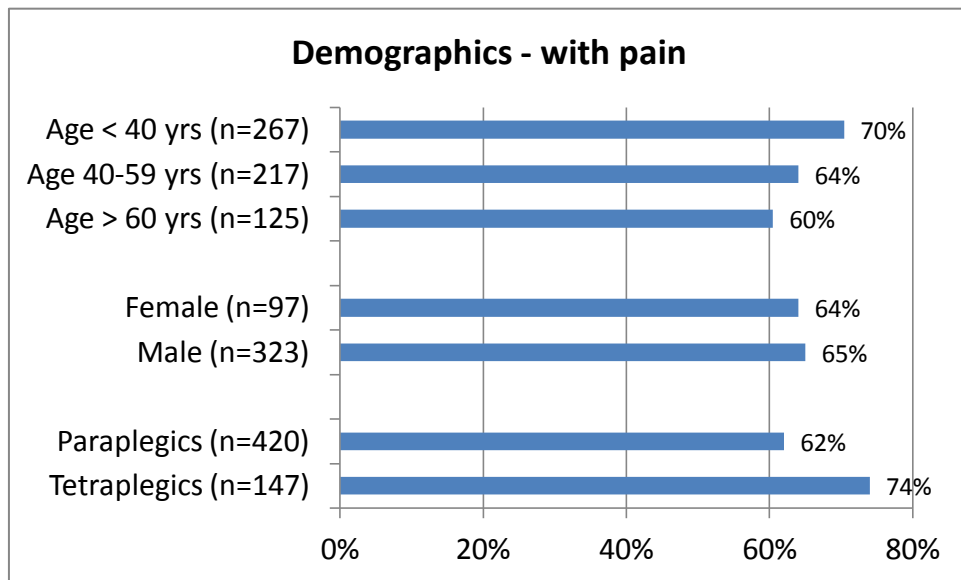


Figure 27 Prevalence of pain according to age, gender and level.

The actual date of injury was not recorded as part of the survey, only year of discharge. As all respondents were first admission patients to a SCIC, time since discharge has been used as an indication of length of wheelchair use. The prevalence of pain in relation to time since discharge in this study group is presented in Figure 28.

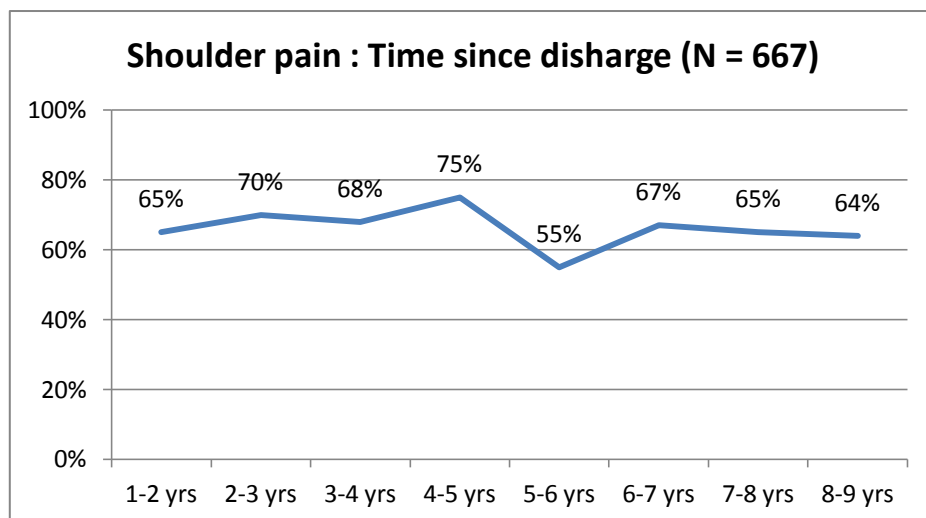


Figure 28 Time since discharge related to prevalence of shoulder pain.

The difference in prevalence between time point '4-5 yrs' and '5-6 yrs' post discharge was explored further using Chi-square statistics. The only relationship found was the distribution of tetraplegic/paraplegic in the populations, 36%/64% for tetraplegic/paraplegic and 27%/73% respectively for the two time points. This was not found to be statistically significant.

4.3.3 WUSPI results

Table 26 presents the overall result for the whole sample for all 15 items. The mean, median and standard deviation (S.D.) are given for each item.

'N' is the number of participants who had performed the activity and given it a score from 0 – 10cm on the VAS. The scores are given in cm, e.g. if a person has a score of 3.2 in a certain item it means that they marked the 10 cm VAS line at 3.2 cm from the '0' (no pain) end of the line for that variable.

The three items with the highest score are highlighted.

Table 26 WUSPI scores for all 15 items for whole study population.

	N =	Mean	Median	SD
Transfer chair/bed	559	1.0	0.3	1.7
Transfer chair/car	537	1.2	0.3	1.9
Transfer chair/bath	498	1.1	0.3	1.8
Load chair into car	371	1.6	0.5	1.3
Push > 10 minutes	548	2.2	1.3	2.5
Push up ramps/slopes	371	2.2	1.1	2.5
Objects down from shelf	488	1.7	0.4	2.3
Put on trousers	496	1.1	0.3	1.9
Put on t-shirt or jumper	563	1.1	0.3	1.8
Put on button down shirt	477	0.8	0.3	1.6
Washing back	473	1.3	0.3	2.1
Usual ADL	570	1.6	0.6	2.1
Driving	416	1.3	0.4	1.9
Household chores	494	1.7	0.5	2.2
Sleeping	581	2.0	0.8	2.5

The following two tables present the WUSPI scores for all the items analysed according to gender (Table 27) and level of injury (Table 28) with the same items highlighted.

Table 27 WUSPI scores for all activities according to gender.

WUSPI activity	Male				Female			
	N =	Mean	Median	SD	N =	Mean	Median	SD
Transfer chair/bed	303	1.0	0.3	1.7	86	1.3	0.3	2.0
Transfer chair/car	290	1.2	0.3	1.8	82	1.3	0.3	2.1
Transfer chair/bath	264	1.1	0.3	1.7	82	1.2	0.3	1.8
Load chair into car	200	1.5	0.4	2.2	47	1.7	0.6	2.2
Push > 10 minutes	287	2.0	1.1	2.3	85	2.5	1.1	2.8
Push up ramps/slopes	287	2.1	1.0	2.4	82	2.2	1.0	2.7
Objects down from shelf	264	1.5	0.4	2.1	72	2.1	0.4	2.9
Put on trousers	267	1.0	0.3	1.7	79	1.5	0.3	2.3
Put on t-shirt or jumper	300	1.0	0.3	1.7	88	1.4	0.3	2.2
Put on button down shirt	262	0.8	0.3	1.5	74	1.0	0.2	1.7
Washing back	246	1.3	0.3	2.0	77	1.5	0.3	2.5
Usual ADL	302	1.6	0.6	2.0	89	1.9	0.5	2.3
Driving	229	1.3	0.4	1.9	53	2.0	0.6	2.4
Household chores	259	1.5	0.5	2.1	81	2.0	0.5	2.4
Sleeping	308	1.9	0.7	2.5	91	2.2	0.9	2.6

Table 28 WUSPI scores for all activities according to level of injury.

WUSPI activity	Tetraplegic				Paraplegic			
	N =	Mean	Median	SD	N =	Mean	Median	SD
Transfer chair/bed	122	1.0	0.3	1.6	403	0.9	0.3	1.6
Transfer chair/car	116	1.3	0.4	2.0	390	1.1	0.3	1.8
Transfer chair/bath	100	1.0	0.3	1.6	367	1.0	0.3	1.7
Load chair into car	52	1.6	0.5	2.3	304	1.6	0.4	2.2
Push > 10 minutes	123	2.8	1.9	2.7	393	2.0	0.9	2.3
Push up ramps/slopes	116	2.7	2.2	2.6	397	1.9	0.7	2.4
Objects down from shelf	89	2.2	0.9	2.6	377	1.5	0.3	2.1
Put on trousers	78	1.5	0.4	2.4	387	0.9	0.3	1.7
Put on t-shirt or jumper	118	1.2	0.4	1.9	408	0.9	0.3	1.6
Put on button down shirt	75	1.2	0.5	1.9	373	0.7	0.2	1.3
Washing back	81	1.6	0.4	2.4	368	1.2	0.3	2.0
Usual ADL	133	2.1	1.1	2.3	404	1.4	0.4	1.9
Driving	74	1.5	1.0	1.7	328	1.2	0.4	1.8
Household chores	85	2.0	1.2	2.2	382	1.5	0.4	2.1
Sleeping	137	2.5	1.2	2.8	408	1.7	0.6	2.3

Independent t-test analysis of the difference in pain score for the activities 'Push > 10 min' and 'Push up slope' revealed no statistical significance for gender.

The difference in pain scores according to level was found to be statistically highly significant for both activities ($p>0.001$).

4.3.4 WUSPI and type of wheelchair.

From the results from the wheelchair provision survey questionnaire it was possible to identify the types of wheelchairs that the respondents were using at the time of completing the WUSPI. The same classification has been used as described in the methodology for the surveys ([Chapter 3.1.2.2](#)). Figure 29 illustrates the range of wheelchairs used by the users with and without pain.

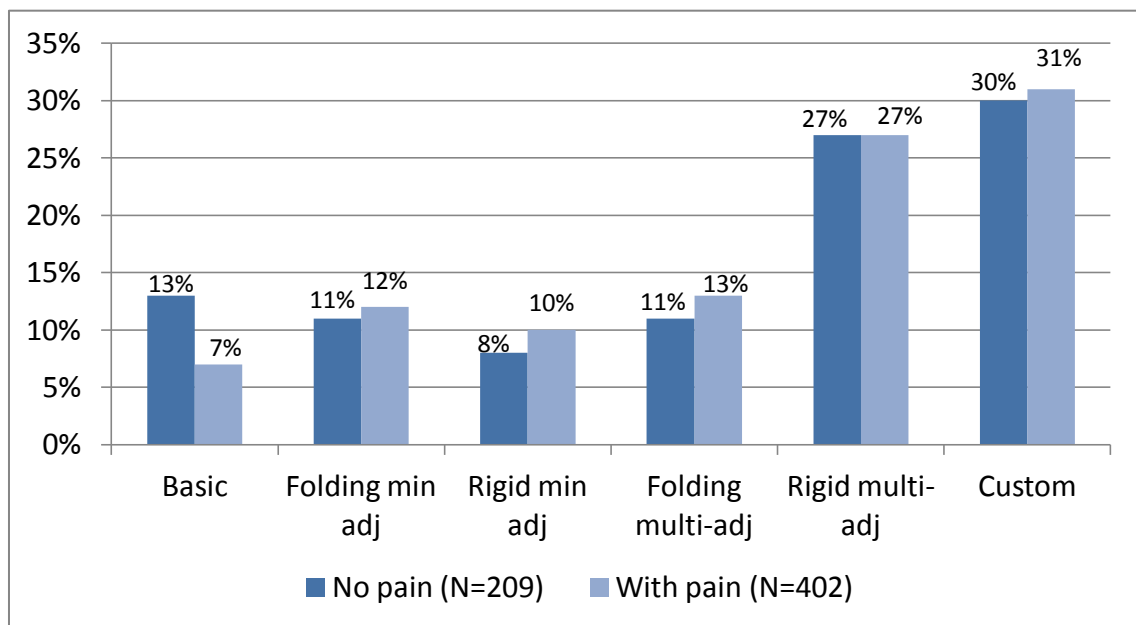


Figure 29 Types of wheelchairs used by the groups 'No pain' and 'With Pain'.

The majority of participants in both the 'no pain' and 'with pain' group used a multi-adjustable or custom wheelchair; 68% and 71% respectively.

In order to establish any difference in the types of wheelchairs used since discharge by the 'no pain' and 'with pain' groups, analysis of the types of wheelchairs used as first and present wheelchairs was performed. The results are presented in Figure 30 for the 'no pain' group and in Figure 31 for the 'with pain' group.

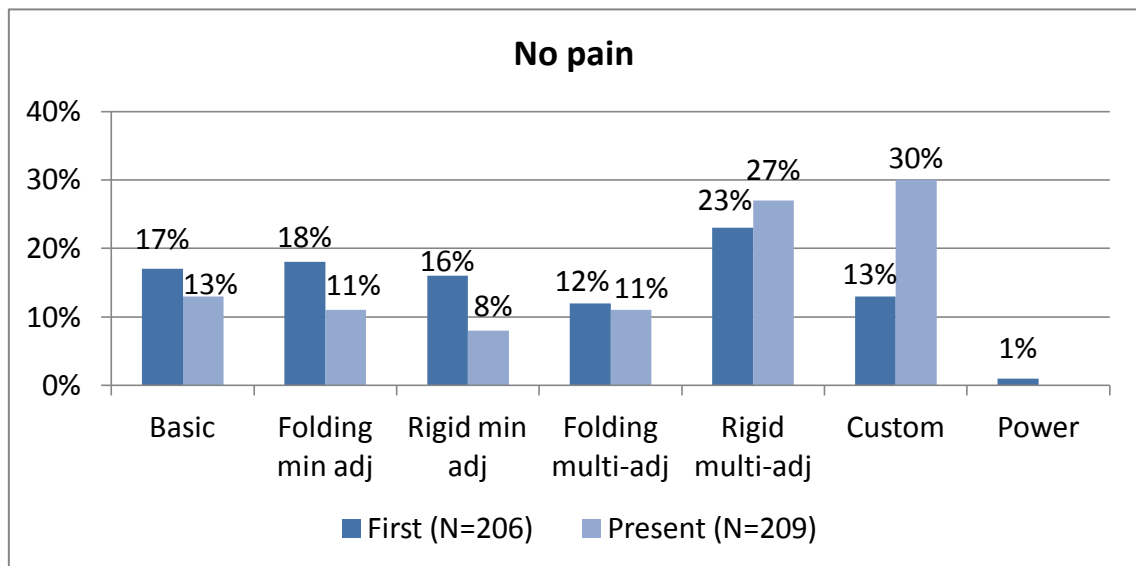


Figure 30 Types of wheelchairs used as 'first' and 'present' by the 'no pain' group.

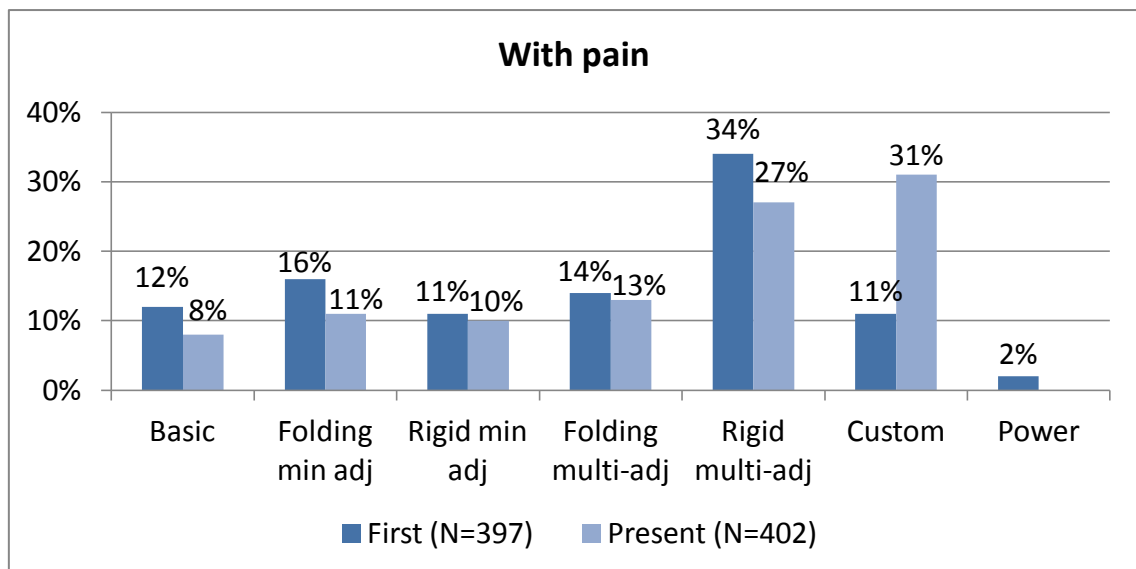


Figure 31 Types of wheelchairs used as 'first' and 'present' wheelchairs by the 'with pain' group.

In order to analyse the effect of wheelchair type on shoulder pain more closely, the WUSPI scores for the activity 'Push for > 10 minutes' and 'Push up slope' were analysed against the type of wheelchair used. For this purpose the wheelchairs were categorised into folding and rigid frame wheelchairs.

Figure 32 Figure 32 presents the severity of pain experienced for the activity 'Pushing for > 10 minutes' for folding frame and rigid frame users respectively.

More severe pain was noted for folding frame users than for rigid frame users for 'Push for > 10 min'. Using Chi-square statistics this was found to be significant at the level of $p=0.01$.

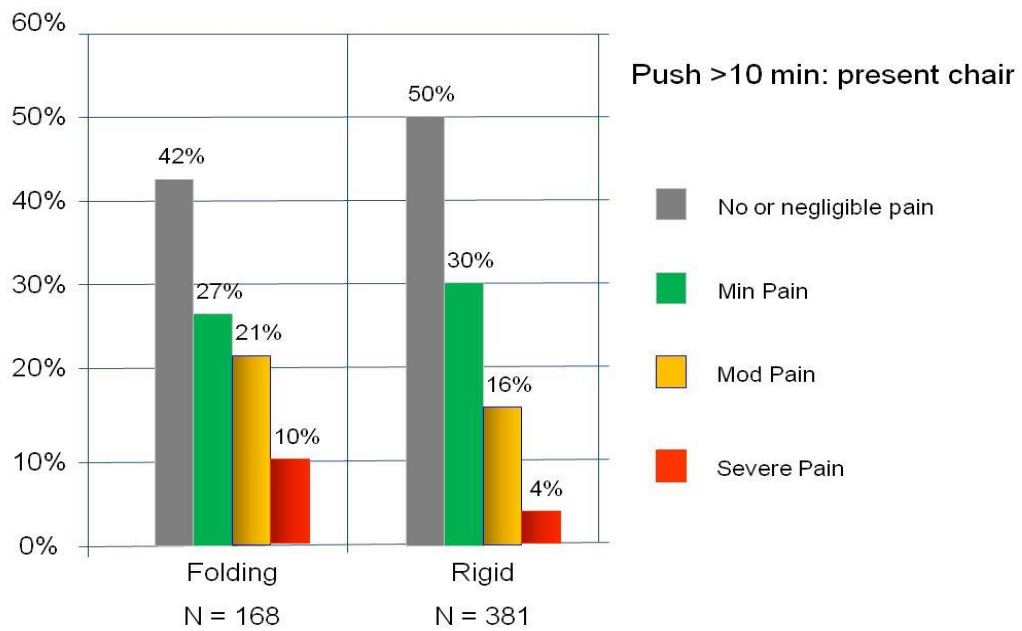


Figure 32 Severity of shoulder pain for pushing for > 10 minutes for folding/rigid frame wheelchair users (N = 549). $p=0.01$.

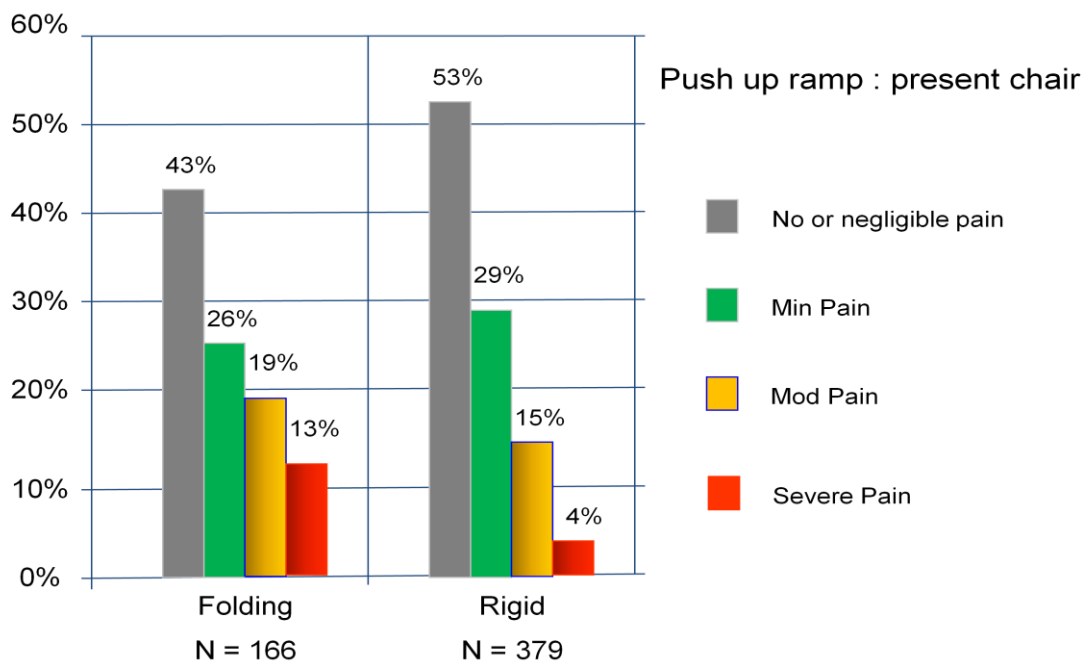


Figure 33 Severity of shoulder pain for pushing up ramp or slope for folding/rigid wheelchair users (N = 545). $p=0.001$.

More severe pain for folding frame users was also noted in the activity 'Push up ramp' (Figure 33). Using Chi-square statistics this was found to be highly significant with $p=0.001$.

As the folding frame / rigid frame grouping covers a spectrum of wheelchairs within each grouping, wheelchair type was collapsed into a new variable, 'basic / non-basic' with 4 groups: basic, minimally adjustable, multi-adjustable and custom. As the only minimally adjustable rigid frame chair available in the UK at the time was the Remploi Roller, there is a dominance of folding frame wheelchairs in the basic and min. adjustable groups.

For the activity 'Pushing for > 10 minutes' more severe pain was noted for basic and minimally adjustable wheelchairs. However pain free propulsion was not related to type of wheelchair (Figure 34). Using Chi-square statistics this result was found not to be statistically significant.

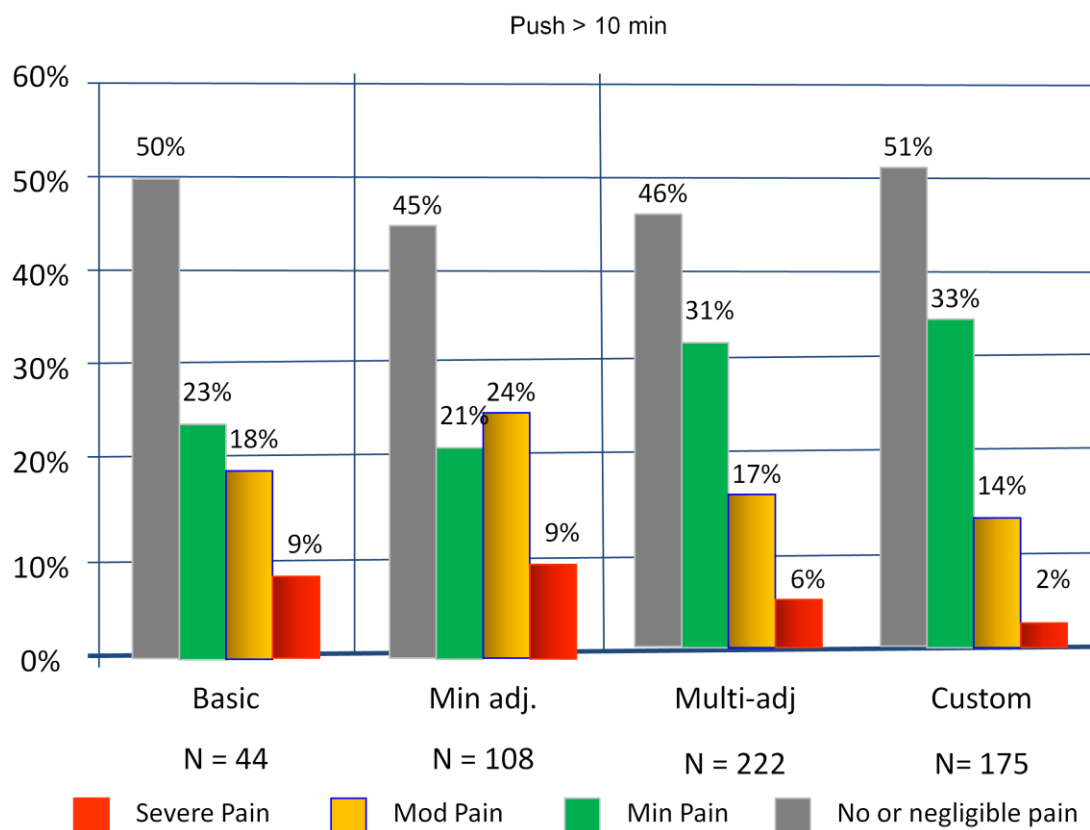


Figure 34 Severity of shoulder pain for pushing for > 10 minutes for basic/non-basic wheelchair users (N = 549). N.S.

The results for the activity 'Push up Ramp' are presented in Figure 35.

More moderate and severe pain was noted for the basic and minimally adjustable wheelchairs than for multi-adjustable and custom wheelchairs. Using Chi-square statistics this was found to be highly significant with $p=0.006$.

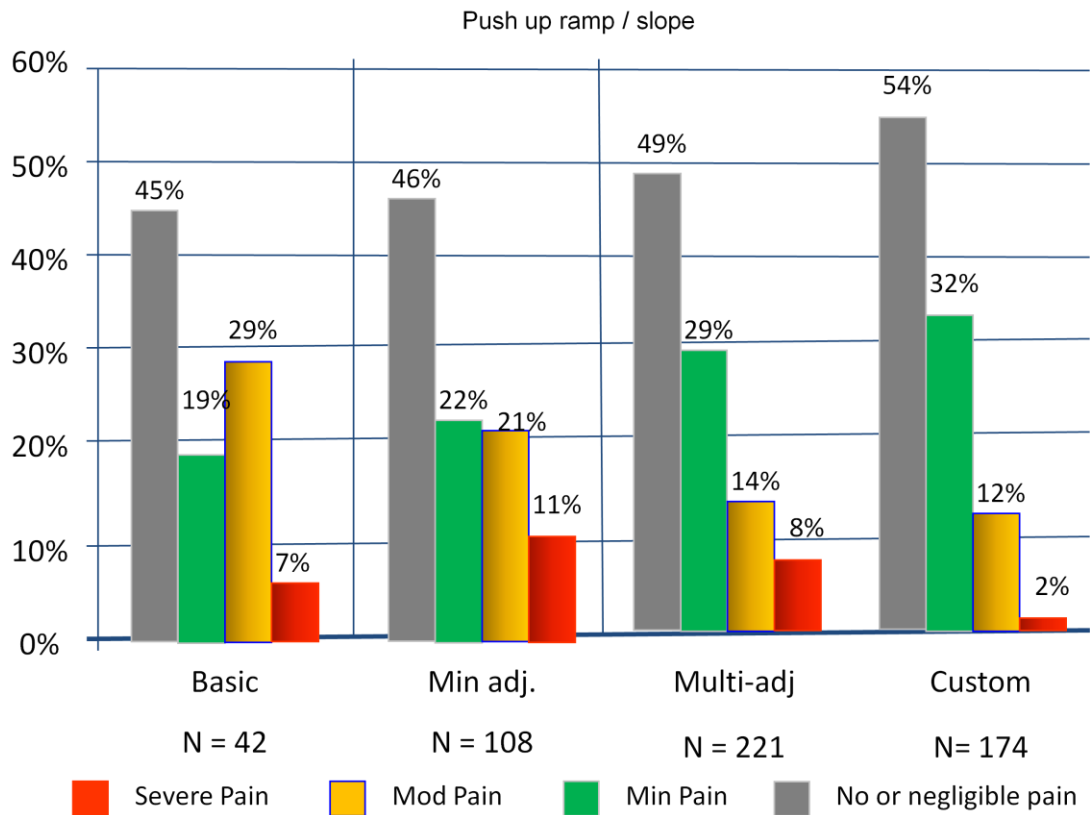


Figure 35 Severity of shoulder pain for pushing up ramp or slope for 'basic/non-basic' wheelchair users (N = 545). $p=0.006$.

This concludes the presentation of the results for the three aspects of this thesis.

5 DISCUSSION

In this section the results for the three aspects of the thesis will be discussed and where appropriate put into the context of research and developments which have taken place since the data was collected.

5.1 Wheelchair Provision Surveys.

The response rate for the surveys was 36% and 43% respectively. In order to boost the response rate in the 1998-2004, survey reminders were sent out. This was felt to have had a positive influence on encouraging people to reply.

The results for age reflect the emerging trend of more people sustaining their SCI at older age. This is largely due to the general population living longer but also the fact that people now tend to lead more active lives in retirement.

5.1.1 *First provision and change*

When the 1991-1997 survey was published (Rose et al. 2002a), the finding that attracted the most attention amongst clinicians was the great number of people that abandoned their first wheelchair within the first year of discharge. As this was linked to the type of wheelchair issued it is not surprising that, in view of the change in the range of wheelchairs provided, the number of people changing early has dropped from 52% in 1991-1997 to 19% in 1998-2004 ([Chapter 4.1.3](#)). The wheelchair that dominated provision on discharge in the 1991-1997 survey was the standard, basic folding wheelchair (53%). This now only accounts for 15% of first long-term provision ([Chapter 4.1.2](#)). The biggest increase was in the rigid, multi-adjustable category which more than doubled on first provision, from 14% to 29%. Not only does this tie in with the recommendations from the Clinical Practice Guideline for the Preservation of Upper Limb Function (Consortium for Spinal Cord Medicine 2005); it also reflects the type of wheelchair which was so clearly preferred as the 'present' wheelchair by the participants in the 1991-1997 survey ([Chapter 4.1.2](#)). In fact, when comparing the distribution of provision for 'present' wheelchair in 1991-1997 with that of 'first' in the 1998-2004 survey, they are almost identical. This

change in provision pattern may be in response to the findings from the 1991-97 survey and the commissioned reports on wheelchair provision as well as to an increased demand from the users.

Another consideration, and possibly a more powerful one, is that some of the new generation of wheelchairs have reduced in purchase price in real terms; the retail price of a Quickie 2 wheelchair ([Sunrise Medical](#)) was £1200 when it was launched in the early 1980s and the retail price is now ~ £1500. The Quickie Rxs is very similar to the Quickie 2 and has a starting retail price of £1125. So although the cost has actually stayed very stable over the last 20 – 25 years, there is no denying that the purchase price of these wheelchairs is far more than that of a standard wheelchair. For comparison, the more standard issue folding frame wheelchair for people with SCI, the Action 3 ([Invacare UK](#)), has a starting retail price of £ 475¹³. However, the research carried out by Cooper *et al.* (1996; 1997a) has demonstrated how the new generation of wheelchairs is far more durable than the standard wheelchair and therefore more cost effective in the long run. Into the equation of the lifetime cost of a wheelchair to a service should be included the cost of repairs and maintenance as well as clinic time spent trying to put things right in a wheelchair which simply may just not be the most appropriate for the purpose.

At the time of the surveys there were no national standards for wheelchair provision. Since then the National Health Service Act of 1977 has been repealed and replaced by the National Health Service (Consequential Provisions) Act 2006 (Department of Health 2006). A summary of the regulations pertaining to wheelchair service provision can be found in the newly published Healthcare Standards in Appendix 1 (National Wheelchair Managers Forum *et al.* 2010). This document includes agreed minimum national standards for provision and best practice and provides the benchmark for services from referral through to assessment and provision. It states that the equipment provided should reflect “the clinical and wider, holistic needs of the user”; that

¹³ Prices are current and the lowest found on the websites of a range of approved Sunrise Medical and Invacare dealerships,

the assessment should include those associated with the user (e.g. family and carers) and consider the environment in which the equipment will be used (page 3). This philosophy is also emphasised in the recommendations from the most recent review of local innovations in wheelchair and seating services (Department of Health Commissioning Team 2010).

A confounding factor in trying to establish national standards for provision is different perceptions of what constitutes clinical need. A clinician's expectation of what an individual may be capable of achieving with the right equipment is likely to be influenced by previous experiences. As mentioned in the literature review, SCI constitutes a very small proportion of the disabled population ([Chapter 2.2](#)). It is not unusual for professionals in wheelchair services to see only a few clients with SCI during their career. Inevitably this will give the clinician a limited experience of the aspirations and capabilities of this particular group of users. Crucially it is also much more difficult in this situation to build up an understanding of the long-term implications of clinical practices. On the other hand, the SCIC therapist only sees patients with SCI and hence builds up great expertise in being able to define the potential rehabilitation outcome of an individual. The SCIC therapist also has the luxury of spending many months with the patient. The Service Standards for patients requiring SCI care state that the recommended length of stay for high tetraplegics is 6 months, 18 – 22 weeks for other tetraplegics and 14 – 17 weeks for paraplegics (South of England Spinal Cord Injury Board 2010; criteria 8.2.2). Whilst the therapist in the SCIC will have the opportunity to continually evaluate the benefits to the user of one wheelchair configuration over another as part of the rehabilitation process, it is far more difficult to get a clear picture of the environment in which the wheelchair will be used after discharge. Due to the large geographical areas covered by SCIC, home visits are rarely possible. In addition, it is not unusual for home adaptations to still be taking place after discharge. Where an individual is waiting for re-housing, interim accommodation may have to be found in order to enable discharge to take place when the rehabilitation is deemed to have been completed. For many, the housing they will be discharged to may be safe but far from ideal. Thus close collaboration and

pooling of skills between the wheelchair service therapist and the SCIC therapist should be strongly encouraged and facilitated.

It was this uncertainty surrounding final outcome following discharge that led to the recommendation of issuing a wheelchair for interim use.

5.1.2 Interim provision

The intention with interim provision was that the SCIC therapist would be able to make a provisional recommendation for a wheelchair which would enable the individual to be discharged. Implicit in the choice of wheelchair for interim use was that the wheelchair would not prevent the user from actively using and consolidating the skills learnt during rehabilitation. The wheelchair service therapist, with the advantage of being able to assess the individual in the home setting, was considered to be in a better position to continue the assessment process after discharge and together with the user decide on the final prescription. This system was implemented in 62% of discharges in the 1998-2004 periods ([Chapter 4.1.2](#)).

When this system was first suggested there was some concern that people might be left with the interim wheelchair for longer than planned. This was indeed the case for 28% of individuals, who were expecting to have the interim wheelchair for < 3 months and for 22% of individuals, who were expecting to have the interim wheelchair for 3-6 months. In contrast, of the people who expected to have the use of an interim wheelchair for > 6 months, 19% ended up having it for less than that.

The questionnaire did not allow for probing deeper into the detail of interim provision, in particular in relation to satisfaction from the user's point of view with this way of managing provision at discharge. Based on the evidence from this survey, the reason for having interim provision for longer than expected cannot be taken as an indication of a delay in providing the long-term wheelchair. It may simply be that the home situation was still not completed or that the user did not yet feel ready to commit to a long-term choice of wheelchair.

The fact that the SCIC provided 36% of the wheelchairs used as interim is an indication of the commitment that these centres have to ensuring that the individual has the use of a wheelchair that is appropriate for their needs on discharge. This is not likely to be a sustainable situation though as the SCIC need to have their assessment stock available within the centres for current in-patients and not be used out in the community. As the SCI person often lives quite a distance from the SCIC it can be notoriously difficult to get equipment back before the first follow-up appointment at the centre, which is not till 6 months post discharge. In effect, the SCICs are bailing out the wheelchair services by supplying wheelchairs for this use. An unintentional consequence of this might be that the true need for interim wheelchairs, both in terms of number and type, is obscured to the wheelchair services.

The reason for including the Red Cross as an option for providing interim use is based on clinical experience from the Seating Clinic at the NSIC. In more recent years some wheelchair services have been unable to meet interim or occasional need and have referred clients to the local Red Cross. This is a worrying trend as the wheelchairs available through the Red Cross are not subject to the same safety and maintenance standards as those supplied via the Wheelchair Service. This option was only used for 1% of the participants in this study. As this is a very unsatisfactory solution for anybody who is dependent on a wheelchair, this situation may also have contributed to the number of wheelchairs made available through the SCIC for interim use.

Although the Red Cross is no longer being used in some areas, it is still the case that, where the Wheelchair Service is unable to provide for occasional user, the individual has to organise hiring the wheelchair from local companies.

5.1.3 Present provision

The changes in distribution in the 1998-2004 survey from first to present provision are far less dramatic ([Chapter 4.1.2](#)). It merely continues the trend toward the multi-adjustable and custom made wheelchairs.

The generally accepted advice from SCIC therapists and experienced users is to defer going for a custom made wheelchair until the new user has a few years

of experience. The attraction of the custom made wheelchair is that it is exceptionally light, typically 6 – 10 kg. The drawback is that, as the name implies, very little can be adjusted on the wheelchair. The rear wheel position can usually be altered in the forward direction, but the seat incline or bucket is fixed as is commonly the backrest angle. Hence the angle of the femur to the pelvis cannot be changed. Typically the inexperienced user needs the backrest higher to start with but over the time this may gradually be brought lower as trunk balance and confidence grow. As the backrest height on a custom made wheelchair in most cases tends to be fixed at manufacture, the temptation is to go for a lower back than the user may be able to cope with. This can lead very quickly to problems with poor posture and pain. It is of concern to note that, according to the results of these surveys, the number of users having custom made wheelchairs as their first long-term wheelchair is on the increase, from 2% to 13%. The fact that more than a third of custom wheelchair users in either survey changed the wheelchair within 3 years of discharge supports the current clinical practice.

Due to the weight benefits of the custom wheelchair, an increase in the number of people using custom-made wheelchairs as experienced users was not unexpected, particularly with the aid of the voucher to fund them.

5.1.4 Change of type of wheelchair

The reduction in the number of people, who abandoned their first wheelchair within a year of discharge in the 1998-2004 survey compared to the 1991-97 survey, is a clear reflection of the change in provision towards the range of wheelchairs preferred by the user. This is further supported by the finding that the likelihood of changing the wheelchair early is no longer linked to the type of first wheelchair ([Chapter 4.1.3](#)). In both surveys the younger age groups were more likely to change the wheelchair early. This may be due to the fact that this is the group of people who are likely to be the most physically active and therefore demanding of their wheelchair. It could also be due to the fact that most lifestyle changes happen during that period of life, e.g. childhood to adulthood, education to employment, establishing family life. The reason why

females were found to be more likely to change the wheelchair early in the 1998-2004 survey is not clear.

5.1.5 Reasons for changing

In the 1991-1997 survey pushability and comfort were the main reasons for change and should be seen on the background of the types of wheelchairs issued as discussed previously.

The reasons for change in the 1998-2004 survey are not quite as simple to interpret ([Chapter 4.1.4](#)). Given that participants were issued with more adjustable wheelchairs, the fact that posture and comfort are so high on the list of reasons for change may indicate that the full scope of adjustment to the user has not been implemented beyond the initial set-up.

The weight of the wheelchair was much more of an issue for the participants in the 1998-2004 survey. This may be a reflection of much greater awareness amongst users of the importance of weight in relation to the risk of developing shoulder pain.

5.1.6 Funding

The main thrust of the surveys was to investigate changes in wheelchair provision in relation to the voucher scheme. The wheelchair services accounted for 88% of the funding of first long-term wheelchairs in the 1991-97 survey ([Chapter 4.1.5](#)). This dropped to 60% in the 1998-2004 survey. However, as a further 25% of wheelchairs were funded using a voucher, the wheelchair services were effectively involved in the funding of 85% of first wheelchairs.

Most wheelchair services would not consider issuing a new voucher within a three-five year period unless there has been a distinct change in clinical need. As mentioned previously ([Chapter 2.4](#)), most SCICs would advise against using a voucher for the first long-term provision because of the recognised period of adaptation needed by most individuals following initial rehabilitation and discharge from a SCIC. The fact that 40% of the people using a voucher for their first wheelchair changed it within the 3 years of discharge supports this clinical recommendation ([Chapter 4.1.5](#)). However for some individuals the

clinical need is very clear and a voucher may be the best and quickest way of getting the wheelchair of choice. For others the use of the voucher on discharge may be a reflection of either the frustration over the time required for the process to run its course from referral to provision of the wheelchair or simply finding the wheelchair offered too unacceptable. The final report into the Voucher Scheme Initiative (NHS Executive & Department of Health 2000) found that many users selected the voucher option due to the shortcomings of the mainstream services and were in fact “‘pushed’ towards the scheme” because of inadequate provision available outright rather than “‘pulled’ towards it due to its inherent attractiveness”.

For the present wheelchair, the wheelchair services funded 45% of wheelchairs in the 1991-97 survey compared to 32% in the 1998-2004 period with a further 34% being funded with the help of a voucher. The use of the voucher may have helped to reduce the number of people who resorted to outright private funding from 42% in 1991-97 to 28% in 1998-2004.

It is sometimes argued that people with SCI can afford to purchase their own wheelchairs as they often have successful compensation claims. It is estimated that only 20-25% of people with SCI will be able to claim compensation and that only half of those will have access to immediate interim settlements (Spinal Injury Association 2011).

The illustration of the different types of wheelchairs funded by the three main sources of funding show that the wheelchairs of choice, when the user has a financial stake in them, are the rigid multi-adjustable and custom wheelchairs ([Chapter 4.1.5](#)). This trend is particularly strong for the present wheelchair. This finding supports the clinical view expressed in the [introduction](#) of this thesis. It is curious though to note that a very small number of users purchase the more basic range of wheelchairs privately even though these types of wheelchairs would be expected to be readily available through the wheelchair services.

Apart from giving the user more choice in wheelchair selection, the introduction of the voucher scheme has impacted on the service in other maybe more subtle ways. As it gives the user a financial stake in the wheelchair, it is natural that

the user becomes much more involved in the process of choosing a wheelchair. Crucially 'the system' now expects the user to become engaged in the process. As most of the vouchers issued are on the independent option, few wheelchair services get involved in the selection process. The voucher scheme not only assumes but relies on a great level of knowledge and engagement on behalf of the user. This is not usually a problem for individuals who have had access to a high level of education through the rehabilitation process in a SCIC, have been exposed to peers with several years' of experience or are themselves very experienced users. For other groups of users the lack of independent (and free) advice can be a real danger when wanting to use the voucher scheme.

There is an inherent disadvantage to the wheelchair service therapists as well if they are not engaging in the independent voucher assessments, particularly with more experienced users. Therapists can learn a great deal from users in terms of what motivates them to choose one wheelchair over another or one particular feature over another. This experience can then be applied in clinical practice when guiding users, who are less experienced or less confident.

The voucher scheme has also enabled wheelchair services and users to be more imaginative in collaborative funding. The private contribution can come from a variety of sources not just the person's private funds. Collaboration between the wheelchair service as the provider of the voucher and agencies such as 'Access to Work' and charities are not unusual.

In 26% and 48% of vouchers issued for first and present wheelchairs respectively, no private contribution was required ([Chapter 4.1.5](#)). A curious incentive for the wheelchair services to issue a voucher is that, if the wheelchair is purchased by the service outright, it is liable to value added tax (VAT), currently 20%. However, as a person with a disability is VAT exempt, issuing a voucher to the full value of the wheelchair (excl of VAT) in effect enables the service to purchase the wheelchair at less cost. Interestingly, the mean value of the voucher and personal contribution in this provision study is more than those reported in the final report on the Voucher Scheme Initiative (NHS Executive & Department of Health 2000). Whereas the mean value of the voucher and the personal contribution was about £1000 each in the provision study, the mean

value published in the report for the voucher was £544 and for the personal contribution £ 367. This may be explained by the fact that the final report covers all types of wheelchair users and acknowledges that people with SCI tended to use a voucher for the lighter (and therefore more expensive) types of wheelchairs. The report also confirms that the independent option is the more popular option for both users and clinicians.

A final example of how the voucher scheme has enabled the services to operate more independently and with greater flexibility is when the user expresses a wish to adapt their manual wheelchair for use with a powerpack or power assist device. There is a growing number of these add-on devices on the market. A study by Arva *et al.* (2001) demonstrated that the power generated to propel a manual was 3.65 times more than when propelling the same chair with a power assist device. These devices are also recommended as part of the strategy to minimise the risk of overuse injuries to the upper limb (Consortium for Spinal Cord Medicine 2005). Some wheelchair services provide powerpacks, others do not. Power-assist devices fall between categories as they are neither manual nor power. Some wheelchair services have overcome this problem by supplying an independent voucher to the full value of the wheelchair with which the powerpack or power assist device will be used. The user can then purchase the device privately. And if anything goes wrong the wheelchair service is not liable.

An unintentional consequence of the Voucher Scheme is that it has brought back to the Wheelchair Service many users who had previously opted out due to dissatisfaction with the options available to them from the service. This has helped the wheelchair services get a more realistic picture of the true number of users entitled to NHS provision.

The final report on the Voucher Scheme Initiative states that there is an overall concern that the scheme favours those who can afford to pay (NHS Executive & Department of Health 2000). The report also presents evidence that in some services the value of the voucher was not based on the value of the wheelchair which would otherwise have been provided by the NHS. In these services

vouchers of a similar value were allocated to all recipients, regardless of clinical needs.

The Voucher Scheme may have improved the individual's choice of wheelchair and opened up opportunities for the user to engage more in the process. The user of today may have changed from being a passive recipient to being an active participant. For the clinician, however, the immediate challenge is to safeguard that the provision of an appropriate wheelchair, based on clinical need and current evidence, does not rely on the user being able to afford to pay towards it.

5.1.7 User Satisfaction.

The reports published in the last decade have been fairly condemning of the wheelchair services as discussed in [Chapter 2.2](#) of this thesis. It is therefore very positive to find such good user satisfaction amongst this user group. There was greater satisfaction with the present wheelchair which might be taken as a further indication that people need time to find out what they need ([Chapter 4.1.6](#)).

A different way of expressing satisfaction with provision would have been to use Quality of Life outcome measures. As mentioned previously, the report on seating services in Scotland used Quality-Adjusted Life-Years (QALY) to document the wider impact of appropriate seating on the whole of the health service (Scottish Executive 2006). The users surveyed for the final report on the Voucher Scheme Initiative (NHS Executive & Department of Health 2000) were also asked how much they felt their voucher wheelchair had improved their mobility and their quality of life. Mobility was reported to have improved a great deal or quite a lot by 79% of the respondents. Quality of life had improved a great deal or quite a lot for 77% of the respondents.

5.1.8 Adjustment of wheelchair.

In the SCI world 'adjustment of a wheelchair' is automatically assumed to have something to do with the rear wheel position. However, to the rest of the wheelchair world it often means adjusting the footplates and armrests. Although the section of the questionnaire relating to 'adjustment' refers specifically to rear

wheel axle adjustability initially, this was not as clearly defined in the subsequent questions. Therefore some of these replies might also refer to adjustment of other parts of the wheelchair as well as the rear wheel axle position.

The results from this study do not support the situation reported by some users that wheelchairs are not being adjusted on delivery ([Chapter 4.1.7](#)). This was only the case for a minority (12%) and the reasons for this cannot be established from this study.

The fact that some users take an active part in the adjustment of their wheelchair is a further indication of the greater engagement of the user with the whole process.

The involvement of the dealer in this aspect of the process is not un-expected given the types of wheelchairs being supplied and the technical knowledge required for this task. It is somewhat surprising though to find that the SCIC are involved in adjusting 13% of the wheelchair supplied as present wheelchairs as they are not likely to have been very actively involved in the assessment for this.

5.1.9 Assessment

It would be expected that the primary responsibility for assessment would be perceived by the user to be by the SCIC therapist for the first wheelchair due to the intensity of wheelchair skills training and trialling going on as part of the rehabilitation process. It is positive to see evidence of collaboration across professions for both first and present wheelchairs. The heavy involvement of the dealer in the assessment for the present wheelchair is not surprising considering the greater sophistication of the wheelchairs supplied ([Chapter 4.1.8](#)).

Apart from the direct benefit to the user, more appropriate immediate wheelchair provision will impact on other areas of the Health Service as well, for example as savings in medication for pain and spasticity or a reduction in secondary deformities requiring surgery. Having separate budgets for each

service can be very limiting to the solutions available to the individual at the centre of the situation. To give one example: it might be far more acceptable not only to the user but to the family as a whole to issue the person with the impairment with a wheelchair with a stand-up facility rather than carry out extensive home adaptations to the kitchen. Although the stand-up wheelchair would be far less expensive to provide than the cost of the adaptations, this would not usually be considered for provision by the Wheelchair Service. This preferred solution could therefore only be implemented if the individual can find a different way of funding the stand-up wheelchair. The absence of joint up funding across services prevents a truly holistic approach to solutions.

Due to the fragmentation of the Health and Social Services, the service that pays for the improved provision, the Wheelchair Service, does not see the financial benefits from it. It is in the interest of the users of the services as well as the NHS as a whole that a system for fairer and more equitable allocation of funds to wheelchair services is developed, based on national guidance on per capita funding (NHS Executive & Department of Health 2000).

5.2 Propulsion Biomechanics

The findings from the 1991-97 national survey helped inform the design of this pilot study investigating changes in propulsion biomechanics in newly discharged people with SCI. Due to the evidence from the 1991-97 survey it was anticipated that some of the participants would be discharged with a basic or minimally adjustable wheelchair and that some might change their wheelchair within the timeframe of the propulsion study (one year). To control for this, testing in their own chair (OC) as well as a control chair (GPV) was included in the design of the study.

In the event, the range of wheelchairs provided for the participants on discharge was more customizable than expected when planning the pilot propulsion study. The range of wheelchairs used by the new users in this pilot study reflected the findings from the later 1998-2004 survey. None of the participants changed their wheelchair within the study period.

The protocol allowed for optimisation of the wheelchair configuration if it was felt to be indicated by the investigators, based on clinical observation and published recommendations for wheelchair set-up.

It had been anticipated that some participants would require optimisation of their wheelchair set-up at six months (T6). However, this proved not to be indicated and the wheelchair configuration used in testing remained unchanged for both own chair and GPV for the duration of the study.

In the one participant where it was felt that there might be scope for optimisation following the test at T6, this proved not to be functional in the home environment.

Hence any changes observed in propulsion biomechanics are due to changes within the individual and not due to the influence of changes in wheelchair configuration.

5.2.1 Population demographics

The new users represented a convenience sample of patients admitted to the LSCIC, Stanmore and the NSIC, Stoke Mandeville. There were fewer female and tetraplegic participants than is typical of the general SCI population, but recruitment was limited by time constraints.

There was a good match between the characteristics of the new and experienced participants.

Due to the small number of participants in the study, caution must be exercised in the interpretation of the results.

5.2.2 Whole group analysis - lino

For ease of comparison, the table presenting the whole group results for the test on lino has been repeated in this section with the findings from the SmartWheel User Group (SWUG) included (Cowan et al. 2008) (Table 29).

Table 29 Whole group results for the test on lino with SWUG findings.

LINO								
	Velocity (m/sec)		Stroke Length (°)		Stroke frequency (Stroke/sec)		Peak F _{res} (N)	
New	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
T0 OC N=18	1.50	0.31	88.4	9.5	0.91	0.08	90.2	20.3
T6 OC N=13	1.54	0.15	91.8	9.1	0.80	0.26	107.69	30.3
T0GPV N=19	1.45	0.18	87.9	9.1	0.95	0.24	90.7	29.2
T6GPV N=13	1.57	0.15	107.7	10.0	0.79	0.22	100.3	22.9
Exp								
OC N=10	1.43	0.36	89.9	12.7	0.86	0.27	101.7	28.7
GPV N=10	1.41	0.26	88.6	13.0	0.84	0.21	97.7	30.3
SWUG	1.20	0.3	100.6	18.0	1.0	0.2	72.3	25.3

The mean values for the whole group indicate a slight increase in velocity on Lino from the test at discharge (T0) to the test at six months (T6). As stroke

frequency decreased from T0 to T6, this increase in velocity was achieved by increasing the stroke length and force (Peak F_{res}). This trend was the same for the test in OC and GPV.

The decrease in stroke frequency from T0 to T6 may be an indication that the user has learnt to 'coast', i.e. allowing the wheelchair to make full use of the momentum generated by each stroke as the arm relaxes between push release and taking up contact on the push rim again. As coasting is dependent on long, powerful strokes this is supported by the increase in stroke length and force. Longer strokes also indicate an improved technique which may be developed over time as trunk control, balance, confidence and familiarity with propulsion improve.

Compared to the experienced users, the new users are faster, particularly at T6. Stroke length is greater at T6 in the GPV whereas stroke frequency is greater at T0 but less at T6. The force exerted by the new users is less than the experienced users at T0, similar at T6 in the GPV, but greater at T6 in OC. Compared to the experienced users in this study, the new users at T6 achieve greater speed by adopting longer and less frequent strokes and by applying greater force (OC).

The increase in force exerted seen in the new users from T0 to T6 might be interpreted as representing an increase in general upper limb strength following discharge back into the community and a return to active life.

However, compared to the findings from the SmartWheel User Group, both new (T0 and T6) and experienced users exhibit greater speed in the test on lino in OC with shorter and less frequent strokes. The increase in speed is achieved by applying greater force.

5.2.3 Whole group analysis - ramp

For ease of comparison, the table presenting the whole group results for the test on the ramp has been repeated in this section with the findings from the SmartWheel User Group (SWUG) included (Table 30).

Table 30 Whole group result for the test on the ramp with SWUG findings.

RAMP								
	Velocity (m/sec)		Stroke Length (°)		Stroke Frequency (Stroke/sec)		Peak F _{res} (N)	
New	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
T0 OC N=18	0.61	0.15	84.5	11.6	0.89	0.1	117.0	19.0
T6 OC N=13	0.83	0.21	88.7	12.1	0.96	0.14	148.1	53.0
T0GPV N=19	0.59	0.12	85.1	12.4	0.88	0.09	114.0	32.5
T6GPV N=13	0.78	0.28	90.3	11.1	0.94	0.09	139.8	46.9
Exp								
OC N=10	0.83	0.49	87.4	18.2	1.01	0.40	129.1	28.2
GPV N=10	0.76	0.44	84.2	13.6	0.99	0.34	126.0	28.4
SWUG	0.70	0.3	94.1	20.6	1.0	0.2	126.2	34.0

It is to be expected that velocity will decrease as the difficulty of the task increases (Newsam et al. 1996). The most difficult and physically demanding task is to propel up a ramp or incline, which can best be described as a succession of first strokes. As no momentum can be built up, the wheelchair essentially has to start from a standstill for every stroke. The technique employed by wheelchair users to climb a ramp is therefore a series of powerful strokes which tend to be shorter with a more rapid return of the hand to the starting position after wheel release to stop the wheelchair rolling backwards. This requires skill, strength and co-ordination.

The difference in the mean values for the whole group on the ramp from T0 to T6 reflects this. Although stroke length and frequency remain similar from T0 to T6 there is an increase in velocity achieved by an increase in Peak F_{res} at T6.

The trend in the results for the new users at T0 and T6 on the ramp is the same for OC and GPV. As the wheelchairs were configured in the same way, this finding is not unexpected.

The results for the experienced users are similar for propulsion in OC and GPV. The velocity achieved on the ramp is very similar for experienced users and new users at T6. It is interesting to note that the experienced users achieve this velocity with less force and slightly shorter and more rapid strokes than the new users.

Compared to the findings from the SmartWheel User Group, both new users at T6 and experienced users were faster with shorter strokes. Stroke frequency and force were very similar for the experienced users and the SWUG results whereas the new users exerted greater force with less frequent strokes.

The general trend in the new users to use greater force than the experienced users or the SWUG participants might indicate a reliance on strength rather than technique. They may not yet have learnt to pace themselves in a given task. In the laboratory setting there may also be an element of a desire to perform well which might affect the results.

5.2.4 Comparison of T0 and T6 propulsion parameters

This discussion in this section will refer only to the results obtained from the 12 new users with a full data set at T0 and T6.

Generally it would appear that the test on the ramp is better at identifying differences in propulsion performance. The only test that showed a higher level of statistical significance for the difference in performance from T0 to T6 was the test for velocity on the ramp in both own chair ($p=0.0001$) and the GPV ($p=0.008$) (Table 9). Velocity is clinically the most obvious indication of an improvement (or deterioration) in wheelchair skills as any change in stroke length, stroke frequency or force will result in a change in velocity.

Although the difference in the initial results for Peak F_{res} from T0 to T6 showed some indication of statistical significance, this was no longer the case when weight normalised.

The following section will discuss results for each variable with reference to the published outcomes and recommendations from the SmartWheel Users Group

(SWUG) (Cowan et al. 2008). For ease of reference the SWUG findings have been summarised in Table 31.

Table 31 Preliminary outcome findings from the SmartWheel Users Group (SWUG) for the selected variables.

	Lino		Ramp	
	Mean	S.D.	Mean	S.D.
Velocity (m/sec)	1.2	0.3	0.7	0.3
Stroke length (°)	100.6	18.0	94.1	20.6
Stroke Frequency (strokes / sec)	1.0	0.2	1.0	0.2
Peak F_{res} (N)	72.3	25.3	126.2	34.0

5.2.4.1 Velocity

Even though the tests were standardised, the mean self-selected speed of this sample for both OC and GPV on lino was faster than that reported by the SmartWheel Users Group. This might be due to a few enthusiastic individuals who propelled at speeds close to or more than 2m/sec.

At T0 most new users were unable to match the 0.7m/sec \pm 0.3 reported by the SmartWheel User Group for propelling up a ramp. As discussed previously, the ramp requires greater strength and skill. The fact that the newly discharged individuals are unable to match the speed of the SWUG database is likely to merely reflect their inexperience with the task and possible lack of strength at that time. This is supported by the increase in mean velocity on the ramp at T6 which exceeds that of the SWUG findings.

As illustrated in [Figure 22](#), most of the new and experienced users demonstrate propulsion at the recommended speed for community participation of 1.06m/sec. This represents the speed required to safely cross a road before the lights change. Only two experienced users did not demonstrate propulsion at

this speed. However, the speed for these tests was self-selected for the task. Participants were not encouraged to propel as fast as they could. Just like speed of walking tends to be increased when crossing a road, so wheelchair propulsion is likely to be faster in the same situation. It would therefore not seem appropriate to advocate using self-selected speeds for propulsion on a smooth surface as an indication of an individual's ability to perform safely in the community setting. This is however a useful clinical outcome measure to have for marginal wheelchair users to help determine if they are capable of reaching and maintaining this speed in a manual wheelchair. This in turn may help the user and clinician to decide whether manual or powered mobility is the more appropriate form of mobility.

5.2.4.2 *Stroke length*

The mean values for stroke length from this study were less than that reported by the SmartWheel Users Group for both lino and ramp, and particularly so at T0. The only result to match the SWUG finding is the mean value for GPV on lino at T6 where the mean value was found to be 110 ± 9.96 for the paired results. However, this result is influenced by one individual (subject New009) producing an extreme stroke length of 198° ([Chapter 4.2.3.2](#)). The result for subject New006 in GPV at T6 could also be challenged as it is much greater than the results produced in OC at T6. The results for both individuals have been checked and are correct according to the original data. However, if the mean value for stroke length at T6 in GPV is calculated without these two individuals, the result is a mean value of 95 ± 9.96 which seems to be more in line with the rest of the results for stroke length on lino.

Stroke length can be linked to wheelchair configuration in the sense that it is not easy to achieve a long stroke if the rear wheel is set in a very stable position, i.e. rearward of the hip of the user. All users in this study had a wheelchair configuration with the rear wheel as far forward as their skill would safely allow them to cope with in a community setting.

Whilst the recommendation from the Consortium of Spinal Cord Medicine is for long, smooth strokes (Consortium for Spinal Cord Medicine 2005), this should

be achieved whilst being mindful of the anatomical position of the shoulder and the posture adopted during the action. The stroke may be lengthened by either reaching further back to get a longer upstroke or leaning forward on the downstroke to maintain hand contact for longer. In clinical practice the longer upstroke is typically observed to be adopted by tetraplegic users as it allows them to use their strong elbow flexors to initiate the movement. Sometimes a long downstroke is accompanied by the user leaning forward, away from the backrest. By adopting either of these strategies in level propulsion, there is a risk that the shoulder will roll into protraction which will encourage shortening of the anterior aspect of the shoulder and lengthening of the posterior aspect, which is not beneficial for maintaining good shoulder alignment. Although a forward lean is expected in an activity like pushing up an incline or going up a kerb, it would not be expected in relaxed propulsion on a smooth surface. In order to achieve an arc of 198° subject New009 would appear to have adopted at least one of these strategies or possibly both. In a clinical situation this finding should help to alert the clinician to a review of propulsion technique in this individual.

5.2.4.3 *Stroke frequency*

The mean values for stroke frequency were less than that reported by the SmartWheel Users Group, particularly at T6 on the Lino (Table 12) and at T0 on the ramp (Table 13). However, the results from this study are in line with other studies reporting stroke frequencies for smooth surfaces ranging from 0.8 to 1.2 strokes/sec (Kotajarvi et al. 2004; Newsam et al. 1996; Richter et al. 2007).

To minimise the effect of repetitive strain on the upper limb it is desirable to have a low stroke frequency. It takes time to perfect slow, co-ordinated strokes. This learning curve is particularly evident in a few individuals who manage to reduce their stroke frequency considerably from T0 to T6 in the test on Lino, e.g. subjects New004 and New005. In contrast, the increase in stroke frequency for subject New019 might warrant closer investigation clinically (Table 12).

5.2.4.4 Peak F_{res}

The mean results for Peak F_{res} for the participants in this study were higher than the findings reported by the SmartWheel Users Group for the test on lino at both T0 and T6 (Table 14) and for the test on the ramp at T6 (Table 15). Quite a few individuals stand out as appearing to rely on force to accomplish the task.

In order to achieve acceleration, the F_{res} needed is proportional to the mass that has to be moved. Hence the recommendation from the SmartWheel Users Group to weight normalise F_{res} by dividing it with the user's weight in order to compensate for any changes in weight. If a person's weight increases, more force has to be exerted to move it.

After normalising F_{res} for user weight the difference in Peak F_{res} between T0 and T6 is no longer statistically significant for either the test on lino or the ramp (Table 16 and Table 17).

Weight has been identified as an important factor in minimising the risk of secondary upper limb complications, in particular median nerve injury (Boninger et al. 1999). When looking at the increase in user weight from T0 to T6, a mere 6 months, several participants have increased their bodyweight by 10 – 15 kg. This may seem excessive for such a short period of time. However, this weight gain should be seen against the background of the severe weight loss which is commonly experienced following a SCI. The weight loss is due to the loss of muscle mass and calcium from bone associated with paralysis (Consortium for Spinal Cord Medicine 2008). Additional problems are initial loss of appetite as well as a physical difficulty in eating if confined to lying flat for a prolonged period. The quality and variety of hospital food might also have a part to play. The user weight at T0 for some users certainly seem to be below average for an adult of average stature (subjects New002, New003, New006, New010 and New 018) with a few with very low adult body weight (subjects New005 and New009) (Table 16).

Typically the individual can be expected to be back to pre-injury weight within a year of discharge. However, the weight gained post-injury tends to be in the form of abdominal fat deposits. Nutritional advice forms an important part of the

patient education in the preparation for discharge in order to prevent them becoming overweight or obese.

It is curious that the recommendation from the SmartWheel Users' Group only includes normalising for the user's weight as the total mass to be overcome also includes that of the seating system (wheelchair and accessories). This consideration is particularly relevant in the clinical setting where the SmartWheel is being used to assess propulsion parameters in one wheelchair compared with another. For this reason normalisation for total mass was performed for this study group. The result remains non-significant.

Whereas initially the force exerted by new users in these tasks may have seemed excessive, after normalisation the difference in force between T0 and T6 no longer seems as dramatic. However, the absence of a standard for recommended levels of force makes it difficult to fully evaluate the importance of these findings.

5.2.5 *New users versus experienced users*

There was a difference in some of the results between new users at T0 and experienced users although this was not found to be statistically significant for either the test on lino or ramp. The difference in performance was particularly evident in the results for the test on the ramp but, as can be seen from the whole group analysis, this was less pronounced at T6 (Table 7). Generally speaking, most of the new users seem to be approximating the performance of the experienced users by T6.

5.2.6 *Propulsion results for new users analysed by type of wheelchair*

As the whole study sample with test data for the two time points is only 12 participants, it is inevitable that the numbers in each wheelchair group will be very small indeed. This analysis was performed in order to investigate if any propulsion trends could be identified between the types of wheelchairs used.

When looking at the difference in the mean values for T0 compared to T6 in this analysis (Table 24) no wheelchair group stands out as being particularly different to any other across all parameters. However, when looking at the

difference in SD from T0 compared to T6, the results for stroke length for the custom wheelchair on lino and for the multi-adjustable wheelchair on the ramp stand out. A large difference in the SD T0/T6 indicates greater variability in performance between individuals using this particular type of wheelchair. The reason for why this might be cannot be established from this pilot study.

There is no obvious reason for the discrepancy in the results for this sample compared to the outcomes from the SmartWheel Users' Group. When comparing results to the findings from the SmartWheel Users' Group it must be remembered that these are based on the mean values of all the individuals entered into this international database. This does not mean that they constitute ideal parameters. As acknowledged by the authors of the SmartWheel Users' Group report themselves, further research is still required to establish the optimal values for stroke length and frequency as well as the safe threshold for force exerted in specific tasks in order to minimise the risk to the upper limb.

This pilot study has established that individuals with new SCI do change their propulsion biomechanics over time and that this is due to the individual rather than the wheelchair. This might seem to indicate that the type of wheelchair provided initially is not important. In this sample all users had their wheelchair set-up in as optimal a configuration as they were able to cope with at that time within their own environment. This enabled them to use all their skills to the full. The fact that little difference showed up in the analysis of wheelchair groups might suggest that it is not so much the type of wheelchair that is important but the fact that the wheelchair used can be configured optimally for that individual at that time.

The findings from this study support the recommendation in [Chapter 5.1.2](#) not to finalise the wheelchair prescription at the time of discharge but to allow for a period of consolidation of wheelchair skills. The indications from this study would suggest that some individuals are still adjusting their propulsion technique at six months post-discharge.

From the findings of this small study it would seem appropriate to schedule into the discharge planning of an individual from a SCIC a follow-up and review of wheelchair needs at around 6 months post discharge.

5.3 Shoulder pain

This section discusses the results from the study investigating the prevalence of shoulder pain in people with SCI, living in the UK and less than 10 years post onset.

It goes on to explore the impact of wheelchair type on severity of shoulder pain and the types of wheelchairs used by the participants.

The study population was representative of the SCI population in general.

5.3.1 Prevalence of pain

The table presented in Chapter 2 of this thesis is inserted again below with the results from this study highlighted for comparison (Table 32). The population size in this study is larger than in any of the other published studies. The overall prevalence of pain for the whole sample was 66% which is higher than the other studies presented here. This is surprising taking into consideration that it is a relatively newly injured population (1 - 10 years post onset).

Both Curtis *et al.* (1999a) and Alm *et al.* (2008) found an association between shoulder pain and increasing age. That was not the case in this study where it was the younger age group (< 40 yrs) that had the highest prevalence of shoulder pain (70%) (Figure 27). This result was found to be statistically significant ($p=0.036$). One possible reason for this could be that the younger age group might be more active users compared to the older age group.

Similar to other studies, tetraplegics were found to have higher prevalence of pain. This result was also found to be statistically significant ($p=0.007$). It is not surprising that tetraplegics would be more at risk of shoulder pain considering the inherent instability of the shoulder girdle following cervical SCI, although it could be argued that paraplegics tend to perform more advanced and strenuous activities.

Similar to other studies, this study found no association between duration of injury and prevalence.

Table 32 Overview of published studies relating to shoulder pain with the addition of the results from this study highlighted.

Author/year	Population	Duration of SCI	Investigations	Prevalence of shoulder pain
Nicholls, 1979	Para + tetra N= 491	Median: 7 year	Symptom survey	51%
Gellman, 1987	Para N= 84	> 1 yr	History Exam	35%
Pentland & Twomey, 1994	Para = 52		Symptom survey	39%
Subbarao, 1994	Para + tetra N= 451		Symptom survey	60%
Curtis, 1999	Para = 103 Tetra = 92	>1 yr (1-13 yrs)	Self-report survey	Para: 42% Tetra: 59%
Ballinger, 2000	Para + tetra N= 89 (all male)	>9 mths 1 - 48 yrs Aver: 10 yrs	Questionnaire Exam Radiographs	30%
Boninger, 2001	Para = 28		Questionnaire Exam; MRI	32%
Alm, 2008	Para = 88	>1 yr 1 - 47 yrs	Questionnaire WUSPI	40%
Rose, 2012	Para = 420 Tetra = 147	1 yr - 10 yrs	Questionnaire WUSPI	Para: 62% Tetra: 74% Overall: 66%

5.3.2 WUSPI results

The results from this study confirm the findings from other studies with regard to the activities causing pain. Of the 15 activities on the WUSPI form, the three

that are consistently reported to be the most problematic are pushing for > 10 minutes, pushing up a ramp or slope and sleeping.

Although the prevalence of pain is very similar between male and female, females reported higher levels of pain than males in all the WUSPI activities ([Chapter 4.3.3](#)).

Most of the other published studies described in [Chapter 2.6](#) and listed in Table 32 studied paraplegics only. Only Curtis *et al.* (1999) analysed tetraplegics and paraplegics separately and found a prevalence of 59% and 42% respectively. Not only was the prevalence of pain higher in this study (74% and 62% respectively) but tetraplegics also reported more severe pain in many of the WUSPI activities, particularly in the activities relating to wheelchair propulsion. The difference in prevalence and severity of pain for pushing for > 10 minutes and pushing up a slope for tetraplegics compared to paraplegics was found to be statistically significant in this study ([Chapter 4.3.3](#)).

It is of interest that the activities relating to transfers do not score that high in the WUSPI results. Studies measuring intra-articular pressures in the shoulder and at the wrist during transfers have found pressures 4-5 times higher than the reported threshold for nerve viability (Bayley *et al.* 1987; Gellman H *et al.* 1988). The findings from these studies give some indication of the pressures applied to the shoulder during transfers and of the inherent risk that this activity poses to the shoulder. Essentially the shoulder is being required to sustain extremely high intra-articular pressures repeatedly, on a daily basis, whilst performing activities, for which it was not designed.

5.3.3 Shoulder pain and wheelchair type

Based on the information given in the national survey it was possible to identify the types of wheelchairs used by the participants. Sixty-eight percent of the whole sample used multi-adjustable or custom wheelchairs. As these form part of the lighter range of wheelchairs it is surprising that the prevalence of shoulder pain for this sample is so high, especially considering the emphasis put on the weight and customizability of the wheelchair in the literature surrounding this

area of study. In order to identify any differences in the types of wheelchairs used by people with pain and those with no pain, the sample was divided into two groups: those with no pain (N = 209) and those with pain (N=402)¹⁴. The range of wheelchairs used by the two groups was found to be very similar ([Chapter 4.3.4](#)). Although the majority of users in either group had multi-adjustable or custom wheelchairs at the time of completing the WUSPI, this might obscure the influence of previous type of wheelchair used. The analysis of first and present wheelchair for the two groups (no pain / with pain) reveal no obvious difference in the types of wheelchairs used apart from for the rigid multi-adjustable wheelchair. Whereas the number of people with this type of wheelchair in the 'no pain' group increases by 4% from 'first' to 'present', there is a drop of 7% in the number of people with pain who use this type of wheelchair over the same period.

Investigating further the relationship between wheelchair type and shoulder pain, the difference in the severity of pain reported by folding frame users compared to rigid frame users was found to be statistically significant for the activity 'Push for > 10 min' ($p=0.01$) and highly significant for the activity 'Push up slope' ($p=0.001$). As both folding and rigid frame wheelchairs can be ultra lightweight with multiple rear wheel axle adjustments possible, the same analysis was carried out but with the wheelchair type split according to rear wheel adjustability. This was felt to give some indication of the influence of weight on shoulder pain as the standard and less adjustable wheelchairs tend to also be heavier compared to the multi-adjustable or custom wheelchairs. The result for 'Push for > 10 min' was found to be non-significant although more severe and moderate pain was noted for the standard and minimally adjustable wheelchair users. However for the activity 'Push up slope' the difference in the levels of pain experienced between the standard/minimally adjustable wheelchairs users and the multi-adjustable/custom wheelchair users was also found to be statistically highly significant ($p=0.006$).

¹⁴ Pain was defined as scoring >1 cm on the 10 cm analogue scale in at least one variable on the WUSPI form.

There is a wealth of evidence to support the recommendation made by the Consortium for Spinal Cord Medicine (2005) that the lighter and more customizable wheelchair should be the wheelchair of choice for the individual with SCI. However, the startling finding from this study is that in spite of the majority of the participants in this study having the recommended type of wheelchair, 66% had developed shoulder pain within 10 years of injury. This helps to remind clinicians and researchers that upper limb pain cannot be prevented or resolved by simply providing a certain type of wheelchair.

As the standard and minimally adjustable wheelchairs are predominantly folding frame wheelchairs, the evidence against the folding frame style of wheelchair as being a major factor in the development of severe shoulder pain would seem to be strong. This study only identifies a link between the folding frame wheelchair and pain – not specifically what it is about this style of wheelchair that seems to predispose the user to shoulder pain. It is undoubtedly true that a folding frame wheelchair tends to be heavier than its rigid frame equivalent. Newer folding frame models of wheelchairs are being marketed as having similar frame properties as rigid frames with ‘lock in’ mechanisms when unfolded. Another factor may be that most folding frame wheelchairs have a fixed 90° angle between the seat and the backrest. In order to achieve a good fingertip-axle position it is usually necessary to drop the rear of the seat between the rear wheels. In a wheelchair with a fixed seat/back angle, this will inevitably lead to a reclined position of the backrest. This configuration is typically used for users with a fixed kyphotic posture to enable them to have horizontal vision. However, for an individual without a fixed kyphotic posture, this wheelchair set-up will tend to encourage the development of one. Associated with kyphotic posture is often a protraction of the shoulders, which will lead to shortening of the anterior and lengthening of the posterior aspects of the shoulder girdle. And so the user may be inadvertently set on the path to developing shoulder pain.

Although identifying the most appropriate wheelchair undoubtedly remains a priority, there is a great danger in focusing too much on the wheelchair without giving equal attention to all the other factors which play a part in this puzzle: wheelchair configuration, posture, wheelchair skills training, transfers including

the use of transfer boards, and muscle strengthening to address the muscle imbalance around the shoulder girdle. This is a complicated and multi-factorial problem and although these other aspects are beginning to attract more attention, very little evidence is to be found in the literature regarding their impact on upper limb pain.

The following section will briefly discuss some of these other aspects of shoulder pain.

5.3.4 Other parts of the puzzle

The problem of muscle imbalance around the shoulder girdle needs to be addressed with careful assessment and tailored exercise programmes. A study implementing a 6 month exercise protocol with a group of 42 wheelchair users was able to show a reduction in the intensity of shoulder pain on average by 39.9% (Curtis et al. 1999b). The protocol consisted of five exercises which included stretching of the anterior aspect of the shoulder and strengthening the posterior aspect.

The presence of pain in early rehabilitation has been found to be a strong predictor for shoulder pain one year after rehabilitation (van Drongelen et al. 2006). This has implications for how the acute phase and the transition from acute to early rehabilitation is being managed. With an increasing number of patients having surgical fixation of their spinal fractures, the length of bedrest has reduced dramatically from 12 weeks for a conservatively managed fracture to sometimes just a week or less for a surgically managed one. Although this reduces the risk of inactivity atrophy to the unaffected parts of the body, there is a risk that this early mobilisation and engagement in rehab activities, such as assisted transfers, exposes the upper limb to activities to which it is ill prepared. As more and more strengthening equipment finds its way into rehabilitation centres there is a danger that patients are being exposed to routine exercise programmes rather than person specific ones. It is essential that the therapist remains fully aware of the actual strength of the individual as well as the balance of muscle power being developed. This requires regular and frequent

re-assessment of ROM and power in order to monitor the effect of any intervention.

Poor posture has been linked to upper limb and neck pain. In a study by Hastings *et al.* (2003) both prevalence and intensity of shoulder pain was reduced two weeks after postural alignment had been improved by lowering the backrest of the wheelchair and bringing it to a more vertical position.

A further consideration is that different postures can have a direct impact on arm position and perceived arm length. A kyphotic or slumped posture will make the arms seem longer in relation to the pelvis; a posture with an uneven pelvis (obliquity) will result in uneven arm length.

It is not always clear whose responsibility it is to adjust the wheelchair and teach the user how to use it and to what level. For those people with SCI who have their rehabilitation in a SCIC there is ample access to wheelchair skills training, often with wheelchair users as the trainers. Adequate wheelchair skills training is an essential part of learning how to use a wheelchair not just safely but also most efficiently. For those who do not go through a rehabilitation centre, the situation is very different. Although the wheelchair services may provide the wheelchair there is no obligation to instruct the wheelchair user beyond the most basic aspects of using a wheelchair.

It seems pointless to provide a wheelchair which has the potential to be finely tuned to the individual's changing need if there is no clear system in place to enable the user to access a skilled individual who is qualified to carry out those adjustments safely and timely.

There are an increasing number of examples of how the commercial sector and clinical practice have responded to the emerging evidence around secondary upper limb injury in manual wheelchair users. The power assist devices mentioned previously are intended to reduce the effort of propulsion without losing the flexibility of a manual wheelchair for transport purposes. Several types of modified handrims have been developed to place the wrist in a better position during propulsion and reduce the strain on the median nerve. The use of sliding sheets and transfer boards are now much more widely used to reduce

the effort of transfers for both the individual and any person assisting. Following studies to establish the length of time required for pressure relief to be effective, lifting is no longer used for pressure relief and has been replaced by prolonged forward or sideways lean (Coggrave et al. 2003).

Taken to the extreme, the best way to reduce the risk of upper limb injury would be to use a hoist for transfers, give everybody powered mobility and a drive-in vehicle. This strategy would neither be financially viable nor acceptable to most individuals with SCI. Apart from an issue of dignity and choice, this would make the individual far more dependent rather than foster independence. Personal assistance would be required in many instances and there would be a complete loss of spontaneity in terms of going out, visiting friends, travelling etc. Many manual wheelchair users feel that if they don't use whatever capability they have, they will lose it. Another school of thought is to 'conserve it to preserve it', i.e. use whatever you have got when you have to but accept help when it is appropriate and acceptable.

As part of the rehabilitation process it is therefore important to sow the seed of future possible interventions at an early stage to make it easier for the individual to accept changes as and when they become desirable rather than wait till they become unavoidable.

6. CONCLUSION

This section of the thesis will summarise the main findings of this thesis and discuss limitations to the studies carried out as part of the thesis. It will conclude with considerations for clinical practice and future research.

6.1 Main findings

6.1.1 Wheelchair Provision Surveys

The evidence from the two surveys show that wheelchair provision in England has shifted away from the more standard range of wheelchairs towards the more customizable range.

This change in provision pattern is reflected in the high user satisfaction and the reduction in the number of people who change their wheelchair within the first year of discharge, down from 52% in the 1991-1997 survey to 19% in the 1998-2004 survey.

The main reasons for changing the wheelchair have changed from 'pushability' and comfort to weight of the wheelchair, comfort and posture.

Interim provision was adopted for 62% of discharges.

The number of wheelchairs funded outright by the Wheelchair Service dropped from 88% to 60% for the first wheelchair and from 45% to 32% for the present wheelchair.

The Voucher Scheme was used to fund 25% of first wheelchairs and 34% of present wheelchairs. The 'lifetime' of a voucher is 3-5 years. Of the first wheelchairs funded by a voucher, 40% were changed within 3 years of discharge. This finding supports the current clinical advice to avoid using a voucher for the first long-term provision.

Use of custom wheelchairs as first wheelchair increased from 2% to 13% over the survey period. More than a third of the custom wheelchairs used as first wheelchairs were changed within 3 years of discharge. This finding supports the current clinical advice not to opt for a custom made wheelchair for the first long-term provision.

6.1.2 Propulsion Biomechanics

The evidence from this pilot study confirms that the propulsion biomechanics in new users change in the first six months post discharge.

By six months the propulsion biomechanics of most of the new users were similar to those of the experienced users.

This finding supports the use of interim wheelchair provision and the recommendation for scheduled follow-up and review of wheelchair needs at 6 months post discharge.

The test on the ramp proved to be more useful in identifying changes than the test on lino.

The results from this pilot study did not correspond to those published by the SmartWheel Users' Group. At six months the new users in this sample moved at greater speed, with shorter and less frequent strokes and using more force (F_{res}) for both the test on lino and on the ramp.

The findings from this study would suggest that the recommendation by the SmartWheel Users' group to weight normalise Peak F_{res} should include the weight of the seating system used.

6.1.3 Shoulder Pain

This study provides updated evidence for the prevalence of shoulder pain in full time manual wheelchair users with SCI in the UK (66%).

In line with previous studies, it identified pushing for more than 10 minutes and pushing up a slope as the activities most likely to cause pain.

This study identified a statistically highly significant association between wheelchair type and severity of shoulder pain. Users with standard, minimally adjustable, folding frame wheelchairs reported greater severity of shoulder pain.

In spite of this strong link between wheelchair type and shoulder pain, the evidence from this study also suggests that the problem of shoulder pain in

manual wheelchair users cannot be solved by recommending a specific type of wheelchair alone. How that wheelchair is being used is equally important.

6.2 Limitation to studies

6.2.1 National surveys

Although much was learnt from the first survey (1991-97) in terms of format and content of the questionnaire, there were still sections of the second survey questionnaire which seemed open to individual interpretation. The sections pertaining to 'change' and 'adjustment' were the obvious ones. The potential for error in the interpretation of the 'change' data was easily identified and could be corrected as explained in [Chapter 3.1.2.3](#). The problems surrounding 'adjustment' are discussed in [Chapter 5.1.8](#).

As the section on interim provision was a new addition it could not be anticipated fully how this might be perceived. There is the potential to confuse 'interim' with 'first' so great effort was made to make clear which one was referred to at any one time. However, the terminology could possibly be improved.

6.2.2 Propulsion biomechanics

The number of participants in the propulsion study was limited due to the time constraints. This study was part of a wider experimental protocol implemented by a team of researchers at ASPIRE Centre of Disability Sciences at the RNOH at Stanmore. It was initially envisaged that 2 participants could be tested per day. As the study period was time limited (12 months) and the clinician researchers were part-time (one day/week) the number of participants seen became limited not by availability of participants but by available test time.

Attendance early in the day for testing proved difficult due to the travel time to the test centre.

A further physical limitation was the time needed to adjust the control wheelchair to replicate the own chair configuration.

In rehabilitation, much emphasis is put on giving back control to the person being rehabilitated. It was interesting – and revealing – to observe how little control participants had over when their carers would attend to assist them in getting ready for the day. For participants dependent on carers, appointments for testing before mid- to late morning were out of the question.

At the time of data collection for this study (2005) the SmartWheel protocol and user group was in its infancy and much has happened since. The data from this study became part of the initial pool of SmartWheel data. Experiences from this study helped to inform changes in the software used with the SmartWheel, in particular the way the information is analysed and displayed to the clinician and wheelchair user. At the time of this study, the graphs displaying the SmartWheel data were very complicated and time consuming to interpret. This aspect of the SmartWheel has since moved on hugely and now has a much more user friendly package.

Although there were very few participants in this study with compromised hand function, one practical problem with using the SmartWheel is the need to only use the pushrim during the tests. This can seriously compromise or indeed invalidate the test for people with weak hand function.

A summary of the considerations for the use of the SmartWheel are given in [Appendix 2.7](#).

6.2.3 Shoulder pain

The main limitation to this study was that it was designed to be part of the wheelchair provision survey and not a study of shoulder pain *per se*. Consequently it does not yield information regarding other aspects related to shoulder pain such as number of transfers per day, time spent in wheelchair and scores for right and left side separately.

Measuring the mark made on the WUSPI scale proved to be surprisingly difficult. The instruction with the WUSPI form is quite clearly to place an 'X' on the line. The standardisation implemented for the measurement in this study, was to use the perpendicular line through the centre of the 'X'. It would seem to

be simpler if the respondent was instructed to intersect the scale with a line in the first place. In this study, the original WUSPI instructions were adhered to.

6.3 Observations and suggestions for future work.

The data collected from the two wheelchair provision surveys contain information that has still not been fully explored and analysed. As it includes information from Scotland and Northern Ireland for both periods it has the scope to explore further the nitty-gritty of geographical differences in wheelchair provision across different regions. This might be of particular interest as the service delivery system in Scotland and Northern Ireland is different to that of England.

In order to fully understand the implications of interim use and how successful and satisfactory this is as a way of managing provision at the time of discharge, further work is required. As all SCI patients return for a follow-up at 6 months a starting point might be to incorporate in the follow-up pro-forma a section on discharge plans and implementation. At the moment there is very little evidence for how well and how timely discharge plans are being implemented. Consultation between SCIC therapists and their wheelchair services is required to explore further the options for managing provision on discharge. As this has implications for access to temporary stock, other stakeholders such as the dealerships and manufacturers should be included in these consultations. The prime objective from a service management point of view is to pool resources and skills and avoid overlap and repetition.

An additional problem in communication between SCIC and Wheelchair Service, or indeed between therapists within a service, is the lack of good documentation to easily illustrate wheelchair configuration. This can make it difficult to ensure that a similar configuration is used, when different wheelchairs are trialled and comparisons made.

To help gather more evidence about people with SCI and wheelchair use it would be helpful if some of the already established and published outcome measures could become part of the standard documentation used within the SCICs. At the moment WUSPI is primarily used once symptoms start to occur.

It could easily be incorporated into the pro-forma documentation used both during rehabilitation and at subsequent follow-up. The form could be modified to include information on the reverse side pertaining to type of wheelchair, weight of user and seating system, configuration, level of use, typical number of transfers per day, transfer aids used, car mobility etc. Over time, this would provide easily accessible key information to help identify further key factors and circumstances.

From a clinician's point of view the similarities in the development and progress of the SmartWheel to that of the interface pressure monitor into clinical practice are quite striking: from a piece of equipment seen purely as a research tool to something that might be useful in clinical practice but is perceived to be too complicated and time consuming to use and far too expensive to justify. Increasing pressures on the clinician to provide objective evidence for recommendations for equipment is seen by some as justification for having a SmartWheel as part of the clinical toolkit. However, it seems that the main benefit of the SmartWheel in the clinical setting is to aid the clinician in making the user understand the implication of one wheelchair configuration over another and one way of pushing compared to another. In other words, it has tremendous educational value. Again the similarities to the interface pressure monitor is striking: initially thought of as being able to provide the finite evidence for using one cushion over another it has become the most powerful tool in educating the wheelchair user about posture and pressure relief. Hence, it has become an integral part in the prevention of secondary complications such as postural deformity and pressure sores. It is not difficult to imagine the SmartWheel following the same path in the quest to optimise wheelchair configuration and propulsion in order to reduce the risk of upper limb injuries.

However, just as the interface pressure monitor, it should be seen as an adjunct to a good clinical assessment and practice; not instead of.

From a clinician's point of view it is perfectly possible to assess velocity and stroke frequency without the use of a SmartWheel. Stroke length can be observed or filmed for user feed-back. In fact, adapting a protocol for gait analysis for wheelchair propulsion would be very simple. The factor that eludes

the clinician is assessing the amount of force exerted during propulsion. Part of the vision for the development of tools like the SmartWheel must be ongoing research to try to identify the safe parameters for the force used in propulsion.

The intention of the propulsion study was to identify the direction of a future, larger study. There are still un-answered questions surrounding the initial year post-discharge for people with new SCI. To fully understand how the user learns, uses and consolidates propulsion technique over time it would be necessary to follow a much larger group over a full year of wheelchair usage, i.e. a two year study. Terrains which are more difficult seem to be better at identifying differences in performance as seen in the test on the ramp in this propulsion study. An alternative might be to use Astra turf. Arguably the users to benefit most from a detailed assessment of propulsion technique would be marginal manual wheelchair users, e.g. tetraplegics. It is very difficult for tetraplegics to negotiate a ramp, whereas propelling on Astra turf would be more realistic if aspiring to be a manual wheelchair user. As mentioned previously, the need to use the pushrim only for testing with the SmartWheel, excludes many tetraplegics from participating in any analysis using the SmartWheel. This is a serious limitation to any study or clinical practice.

In view of the findings from the shoulder pain study, inclusion of wheelchair type in a future propulsion study might yield further information to help understand the association between shoulder pain and wheelchair type.

It is evident from the literature that much effort has been put into studying the effect of wheelchair configuration and propulsion on upper limb pain. However, the two aspects of ADL that have been directly affected by the new design of wheelchair, in particular the rigid frame wheelchair, are transfers on/off the bed and loading the chair in/out of the car.

Transfers from wheelchair to/from bed were traditionally carried out in a long-sitting position, i.e. the legs straight out with heel resting on the bed. This provides a larger base for the transfer and is therefore more stable. It does however require a great deal of strength as the body has to be lifted clear of the surface. This method also helped to compensate for the inherent forward

instability of the traditional standard wheelchair. Even in its most stable position the rear wheel of a lightweight wheelchair is further forward than the traditional set-up. The more forward position of the rear wheel has reduced the available space at the side for a sideways transfer. In other words the person has to come further forward on the seat in order to clear the rear wheel. For this reason a pivot style transfer is often the preferred method. For this transfer, the feet stay either on the footplate or are placed on the floor and serve as a pivot point for the body during the transfer. As the base is smaller it requires more balance. As the body leans forward, the legs also act as props (even though paralysed) and a lot of the weight is transferred through them. This style of transfer therefore requires less strength and has a bigger rotational element as the body moves through 90°. Although transfers have been identified as being part of the shoulder pain problem, there have been no studies investigating the effect of the different style of transfer on the shoulder girdle and the relative risk of injury to the shoulder. Without this information it is not clear how clinical practice might be changed to reduce the risk.

In relation to rotator cuff tears, the suspicion is that propulsion wears it but transfer tears it.

The loading of the wheelchair into the car has changed from rolling it in behind the passenger seat to physically lifting it in across the body of the user and placing it on the passenger seat or on the back seat of the car. As the wheelchair is modular this usually requires taking it apart and lifting each part into the car. Although this reduces the weight lifted, it increases the number of times that the arm has to go through the same arc. The traditional way of rolling the chair in could still be used with a folding frame chair, but changes in car design with much greater central consoles have made this style of transfer almost obsolete. A study analysing the forces involved in loading the wheelchair would help to inform what changes in techniques could be implemented to minimise the risk to the shoulder. A collaborative study with a group of subjects from continental Europe would yield additional information as they load the wheelchair from the opposite side.

It is imperative that, in the quest to minimise the risk of overuse injuries to the upper limb, all aspects of the problem are addressed in clinical practice. An appropriate wheelchair and optimal wheelchair configuration are absolutely key to this, but so is education in wheelchair skills, maintenance of good posture, understanding what constitutes best transfer techniques and imparting to the user an understanding of how to maintain good muscle balance around the whole of the shoulder.

The wheelchair is often compared to a pair of shoes. Most of us have more than one pair of shoes but only one wheelchair can be prescribed. Hence, it is inevitable that a wheelchair is usually a compromise – should it be the hiking boots or the slippers? The smart shoes or the wellies? Only the person using the wheelchair can make that decision based on the information given to them and the experience they gain from trialling different wheelchairs.

There may be a danger that clinicians and researchers see different wheelchair types as either 'good' or 'bad', and consciously or unconsciously impart this view to the user. The challenge for the clinician is to use skills *and* tools to identify the most *appropriate* wheelchair for an individual at that particular point in their life. It is essential to understand that the mobility needs of an individual with an impairment are not static through life and the service delivery systems need to be sufficiently flexible to address these needs as they change.

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1 APPENDIX 1 - Documentation used in national surveys

1.1 Questionnaire: Survey 1991-1997

**National Survey of Wheelchair Provision
To
People with Spinal Cord Injury
Questionnaire**

(Please **print** answers or \surd as appropriate)

Personal information: Your age: Are you male []; or female []
Date/year of first discharge from spinal unit: Level of injury:

1. Wheelchair use: Please \surd the statement which best describes your situation when you were first discharged from the spinal unit and the statement that applies to you now.

	On discharge	Now
I am a full time wheelchair user	[<input type="checkbox"/>]	[<input type="checkbox"/>]
I spend part of my time on my feet and part in the wheelchair	[<input type="checkbox"/>]	[<input type="checkbox"/>]
I only use my wheelchair for long distances and sports	[<input type="checkbox"/>]	[<input type="checkbox"/>]

2. Wheelchair Type: Please give as much information as you can about your wheelchair.

a. Please \surd the type of manual wheelchair supplied **at the time of first discharge** from the spinal unit and the type of wheelchair you use as your main wheelchair **now**. If you use more than one wheelchair now, please \surd the type under '**Other chair(s)**'.

	1 st chair	Present chair	Other chair(s)
'Ministry' (red/grey or grey/black)	[<input type="checkbox"/>]	[<input type="checkbox"/>]	[<input type="checkbox"/>]
Carters/Everest&Jennings type	[<input type="checkbox"/>]	[<input type="checkbox"/>]	[<input type="checkbox"/>]
Carters Sovereign	[<input type="checkbox"/>]	[<input type="checkbox"/>]	[<input type="checkbox"/>]
Carters Active	[<input type="checkbox"/>]	[<input type="checkbox"/>]	[<input type="checkbox"/>]
Remploy Roller; rigid frame	[<input type="checkbox"/>]	[<input type="checkbox"/>]	[<input type="checkbox"/>]
Remploy Roller; folding frame	[<input type="checkbox"/>]	[<input type="checkbox"/>]	[<input type="checkbox"/>]
Action 2000	[<input type="checkbox"/>]	[<input type="checkbox"/>]	[<input type="checkbox"/>]
Suntec SL; folding, no axleplate	[<input type="checkbox"/>]	[<input type="checkbox"/>]	[<input type="checkbox"/>]
Suntec SX; folding, with axleplate	[<input type="checkbox"/>]	[<input type="checkbox"/>]	[<input type="checkbox"/>]
Suntec SRT; rigid frame	[<input type="checkbox"/>]	[<input type="checkbox"/>]	[<input type="checkbox"/>]
Quickie Rx, Breezy; folding, no axleplate	[<input type="checkbox"/>]	[<input type="checkbox"/>]	[<input type="checkbox"/>]
Quickie 2; folding with axleplate	[<input type="checkbox"/>]	[<input type="checkbox"/>]	[<input type="checkbox"/>]
Quickie GP range; rigid frame	[<input type="checkbox"/>]	[<input type="checkbox"/>]	[<input type="checkbox"/>]
Swede Cross; folding frame	[<input type="checkbox"/>]	[<input type="checkbox"/>]	[<input type="checkbox"/>]
Swede Elite / Act; rigid frame	[<input type="checkbox"/>]	[<input type="checkbox"/>]	[<input type="checkbox"/>]

Other type not listed (please state if '1st', 'present' or 'other'):

.....

b. If you have changed the **type** of wheelchair since discharge, how soon after discharge did this change happen –

Less than 1 year	[]
1 – 3 years	[]
More than 3 years	[]

c. What was the reason for changing the type of wheelchair? (*√ more than one if necessary*)

Comfort	[]
'Pushability'	[]
Image	[]
Posture	[]
Durability	[]

Other (*please state*):

d. If you use more than one wheelchair, please indicate what it is used for (*√ more than one if necessary*) -

Upstairs	[]
Sports/leisure	[]
Work	[]
Outdoors	[]
Powered mobility	[]

Other (*please state*):

3. Funding. Please *√* how your wheelchair(s) have been funded:

	1 st chair	Present chair	Other chair(s)
Wheelchair Service	[]	[]	[]
Privately	[]	[]	[]
PACT (Formerly 'Manpower Services')	[]	[]	[]
Charity	[]	[]	[]

Other (*please state*):

4. Assessment. Please *√* who assessed you for your wheelchair(s)?

	1 st chair	Present chair	Other chair(s)
Spinal unit therapist	[]	[]	[]
Wheelchair Service therapist	[]	[]	[]
Dealer	[]	[]	[]

Other (*please state*):

5. Name of Wheelchair Service:

At the time of your first discharge:

Now (if different):






If you have any other comments, you are very welcome to attach them on a separate sheet. Please return the questionnaire as soon as possible, using the s.a.e. enclosed.

Thank you for your time.

1.2 Questionnaire: Survey 1997-2004
(Teleform format)

1.3 Guide to wheelchair classification

Guide to wheelchair classification

	Description	Example	Photographic example
Group 1	Basic folding frame – rear wheel position is fixed	E&J (see photo), Carters, 8L/8BL	
Group 2	Folding frame with minimal adjustability of rear wheel position. No camber possible.	Sovereign, Suntec SL, Breezy (see photo), Zipper, Action 2000	
Group 3	Rigid frame with minimal adjustability of rear wheel position. No camber possible.	Remploy Roller	No longer available
Group 4	Folding frame with multiple rear wheel positions incl. camber.	Quickie 2/RXS, Etac Cross, Kuschall Ultralite (see photo).	
Group 5	Rigid frame with multiple rear wheel positions incl. camber.	Quickie GPV, K4, Etac Elite/Act (see photo)	
Group 6	Custom made	RGK (see photo), Cyclone, Chevron	

1.4 Participant information sheet (adult)

Survey of wheelchair provision to people with spinal cord injury.

Participant Information Sheet.

You are being invited to take part in a nationwide survey looking into wheelchair provision to people with spinal cord injury. Before you decide how to respond it is important for you to understand why the survey is being conducted and what it will involve. Please take the time to read the following information carefully and discuss it with others if you wish. Ask us if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part.

Thank you for reading this.

Purpose of survey.

As a wheelchair user it is important that you have the correct wheelchair to enable you to be as active and comfortable as possible. In 1998 all the spinal units in the UK carried out a survey investigating the types of wheelchairs being provided at the time of discharge from the spinal unit and the types of wheelchairs being used over a period of time following discharge. The survey covered the period 1991-1997 and just under 1000 people took part. From this survey we know that a great number of people abandoned the wheelchair supplied by the wheelchair service within the first year of discharge in favour of a lighter and more adjustable or custom-made wheelchair. The survey also highlighted the great differences in the types of wheelchairs on offer from area to area. Since the first survey there have been some changes to how wheelchairs are funded. The NHS Voucher Scheme was introduced to offer the individual the option of part funding a more sophisticated wheelchair of their choice. The feed-back from users of the voucher scheme seems to indicate that the scheme is being used in different ways by different services.

We would now like to repeat the survey to establish how wheelchair provision may have changed since the first survey. The information gathered will give us valuable information on aspects of wheelchair provision from the user's perspective. This will be used to develop the way we manage this aspect of the rehabilitation of people with spinal cord injury in the future. It will also help the spinal unit therapists recommend the most appropriate wheelchair.

Some studies have linked shoulder pain to manual wheelchair use. At the moment we have no idea how big this problem is in the UK and would like to take this opportunity to ask you to also complete the questionnaire on shoulder pain as part of this study.

Selection of participants.

All individuals who have been discharged from a UK spinal unit with a wheelchair between 01.01.1997 and 31.12.2004 have been invited to take part in this study. According to our records you have been identified as fulfilling this criteria. The questionnaire enclosed is coded and numbered as this enables us to know which spinal unit you are linked to and will help us to establish differences in provision from area to area. Your reply will remain completely confidential and your identity will not be known to anybody outside of your spinal unit.

Do you have to take part?

Taking part in this study is completely voluntary and your decision will not affect your care in any way. However the more people who return the questionnaire, the more weight the results will carry.

What to do next.

We hope you will find the time to complete the questionnaire and return it using the enclosed pre-paid envelope.

Contact for further information and help.

If you need help completing the questionnaire or have any questions please telephone 01296 315887 and leave a message with your telephone number and we will get back to you as soon as possible.

Thank you for taking the time to read this.

1.5 Participant information sheet (child)

Survey of wheelchair provision to people with spinal cord injury.

Participant Information Sheet.

On behalf of your child you are being invited to take part in a nationwide survey looking into wheelchair provision to people with spinal cord injury. Before you decide how to respond it is important for you to understand why the survey is being conducted and what it will involve. Please take the time to read the following information carefully and discuss it with others if you wish. Ask us if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part.

Thank you for reading this.

Purpose of survey.

As a wheelchair user it is important that your child has the correct wheelchair to enable him/her to be as active and comfortable as possible. In 1998 all the spinal units in the UK carried out a survey investigating the types of wheelchairs being provided at the time of discharge from the spinal unit and the types of wheelchairs being used over a period of time following discharge. The survey covered the period 1991-1997 and just under 1000 people took part. From this survey we know that a great number of people abandoned the wheelchair supplied by the wheelchair service within the first year of discharge in favour of a lighter and more adjustable or custom-made wheelchair. The survey also highlighted the great differences in the types of wheelchairs on offer from area to area. Since the first survey there have been some changes to how wheelchairs are funded. The NHS Voucher Scheme was introduced to offer the individual the option of part funding a more sophisticated wheelchair of their choice. The feed-back from users of the voucher scheme seems to indicate that the scheme is being used in different ways by different services.

We would now like to repeat the survey to establish how wheelchair provision may have changed since the first survey. The information gathered will give us valuable information on aspects of wheelchair provision from the user's perspective. This will be used to develop the way we manage this aspect of the rehabilitation of people with spinal cord injury in the future. It will also help the spinal unit therapists recommend the most appropriate wheelchair.

Some studies have linked shoulder pain to manual wheelchair use. At the moment we have no idea how big this problem is in the UK and would like to take this opportunity to ask you to also complete with your child the questionnaire on shoulder pain as part of this study.

Selection of participants.

All individuals who have been discharged from a UK spinal unit with a wheelchair between 01.01.1997 and 31.12.2004 have been invited to take part in this study. According to our records your child has been identified as fulfilling this criteria. The questionnaire enclosed is coded and numbered as this enables us to know which spinal unit your child is linked to and will help us to establish

differences in provision from area to area. Your reply will remain completely confidential and the identity of you and your child will not be known to anybody outside of your spinal unit.

Do you have to take part?

Taking part in this study is completely voluntary and your decision will not affect the care of your child in any way. However the more people who return the questionnaire, the more weight the results will carry.

What to do next.

If you are happy to take part in this survey, we hope you will find the time to complete the questionnaire with your child and return it using the enclosed pre-paid envelope.

Contact for further information and help.

If you need help completing the questionnaire or have any questions please telephone 01296 315887 and leave a message with your telephone number and we will get back to you as soon as possible.

Thank you for taking the time to read this.

1.6 Invitation to participate (adult)

On individual headed paper

[Subject Name and address - optional]

Date: of posting

Dear [Name]

Survey of wheelchair provision to people with spinal cord injury

You are being invited to take part in a survey looking at changes in wheelchair provision to people with spinal cord injury. Before you decide whether to complete the enclosed questionnaire please take the time to read the information sheet carefully.

Taking part in this study is completely voluntary. However the more people who return the questionnaire, the more weight the results will carry. We hope you will find the time to complete the questionnaire and return it using the enclosed pre-paid envelope. Even if you no longer use your wheelchair please return the questionnaire.

If you need help completing the questionnaire or have any questions please telephone 01296 315887 and leave a message with your telephone number and we will get back to you as soon as possible.

We hope you will feel able to participate in this study and lend us your support in our efforts to improve wheelchair provision for people with spinal cord injury.

Please return the completed questionnaire by [one month after posting] using the enclosed pre-printed envelope.

Thank you for taking the time to read this.

Kind Regards

(Name of local investigator)

1.7 Invitation to participate (child)

On individual headed paper

[Name and address of child]

Date: of posting

Dear parent/guardian,

Survey of wheelchair provision to people with spinal cord injury

On behalf of your child you are being invited to take part in a survey looking at changes in wheelchair provision to people with spinal cord injury. Before you decide whether to complete the enclosed questionnaire please take the time to read the information sheet carefully.

Taking part in this study is completely voluntary. However the more people who return the questionnaire, the more weight the results will carry. We hope you will find the time to complete the questionnaire and return it using the enclosed pre-paid envelope. Even if the wheelchair is no longer being used please return the questionnaire.

If you need help completing the questionnaire or have any questions please telephone 01296 315887 and leave a message with your telephone number and we will get back to you as soon as possible.

We hope you will feel able to participate in this study and lend us your support in our efforts to improve wheelchair provision for people with spinal cord injury.

Please return the completed questionnaire by [one month after posting] using the enclosed pre-printed envelope.

Thank you for taking the time to read this.

Kind Regards

(Name of local investigator)

2 APPENDIX 2: PROPULSION BIOMECHANICS

2.1 Participant information sheet – new user



RNOH Stanmore
Brockley Hill
Stanmore
Middlesex
HA7 4LP

Tel: 020 8954 2300

www.rnoh-stanmore.org.uk

**ROYAL FREE AND UNIVERSITY COLLEGE LONDON MEDICAL SCHOOL
ASPIRE CENTRE FOR DISABILITY SCIENCES
and
ROYAL NATIONAL ORTHOPAEDIC HOSPITAL TRUST
PARTICIPANT INFORMATION SHEET**

The purpose of this consent form is to provide you with the information that you need to consider in deciding whether to participate in a research study which will enable wheelchair users to assess their propulsion ability, achieve greater levels of mobility with less risk of injury.

Study title: Workshop for optimisation of wheelchair selection and user performance

Purpose of Research Project

Some wheelchair users report pain and loss of strength in their arms and shoulders after many years of manual wheelchair propulsion. These symptoms are consistent with repetitive strain injury produced during wheelchair propulsion and can affect the tendons, ligaments and joints of the arm and shoulder. In this study we plan to measure the forces generated during wheelchair propulsion and the metabolic energy cost for people with a recent spinal cord injury so that we can establish a protocol for the future to enable us to fit wheelchair more effectively and reduce the risk of injury resulting from long term wheelchair use. This protocol will compare a series of measurements obtained at the time you are provided with your first wheelchair and then over the next twelve months at 3 monthly intervals. We will also compare your measurements with similar wheelchair users with a much longer period of experience in using their wheelchair.

Procedure

We will ask you to propel two different wheelchairs in a number of test situations that our experiences users have suggested are representative of those found in everyday wheelchair use. These will include propulsion along a lino floor, a flat carpet, a ramp, a slope and set of wheelchair rollers. One wheelchair will be your own and the other will be a control chair carefully setup to match your body build, physical strength and level of spinal cord injury.

Men will be asked to remove their shirts and women will be provided with a vest. We will attach plastic markers with medical grade double-sided tape to the skin on your arm and trunk. A camera system will be used to measure the position of the markers throughout these tests and will enable us to calculate the motion of your body, in particular arms trunk and shoulders during wheelchair propulsion.

We will fit you with a special face-mask attached to a collection device that you can wear or that will be attached to the back of your wheelchair. This will not interfere with your breathing in any way, but will allow us to measure how much oxygen you consume while propelling each wheelchair. We will also fit your wheelchair with a measurement device (Smartwheel) that will allow us to estimate the forces you produce when propelling your wheelchair.

Before each test we will attach a tether to your wheelchair so that we can pull it forward at speeds up to walking speed while measuring the rolling resistance of the wheelchair while you are sitting in the wheelchair.

If you decide to take part in this study, you will be invited to attend a full day assessment at the Royal National Orthopaedic Hospital at the time you are provided with your first wheelchair and then over the next twelve months at 3 monthly intervals. Your out of pocket expenses will be paid for by the project.

There are no expected risks associated with this study, other than those normally associated with wheelchair use. This study may produce a direct benefit to you now as an individual, and it could benefit you and many other wheelchair users in the future, as well as helping clinicians understand how to provide assessments that can have the greatest benefit in terms of optimum wheelchair propulsion, efficiency and reduce the risks of secondary injury resulting from long terms wheelchair use.

All information about you obtained during the study will be kept in files that will be kept confidential.

Taking part in this study is completely up to you. You can refuse to take part or withdraw from the study at any time and such a decision will not affect you care in any way.

If you have any questions, you can reach Professor Ferguson-Pell at 0208 909 5471 and he will do his best to answer them.

2.2 Consent form



RNOH Stanmore
Brockley Hill
Stanmore
Middlesex
HA7 4LP

Tel: 020 8954 2300
www.rnoh-stanmore.org.uk

CONSENT TO PARTICIPATE IN A RESEARCH STUDY

Title: Workshop for optimisation of wheelchair selection and user performance

I agree to take part in this study. I have read the Patient Information Sheet for this study and I understand what will be required of me if I take part in this study.

My concerns regarding this study have been answered by Professor Ferguson-Pell or his colleagues to my satisfaction. I understand that taking part is up to me and that I can withdraw from the study at any time without giving a reason and without affecting my normal care and management. I have read the above and agree to enter this research study.

Signing this form does not alter any of my legal rights. I have been informed of the procedure described above with its possible risks and benefits. I have been given a chance to ask any and all questions I have. I understand that, if I can think of more question later, Professor Ferguson-Pell or his colleagues will answer them for me. I can reach them at 0208 909 5471. If these questions are not answered to my satisfaction I also understand that I may contact the secretary of the chairman of the Joint Research and Ethics Committee (020 909 5314) which has approved this study.

I understand that:

In case of emergency, the Royal National Orthopaedic Hospital Trust will give me emergency medical care if the medical staff of the hospital think it is needed. If care cannot be given at the Royal National Orthopaedic Hospital Trust, then Professor Ferguson-Pell or his colleagues will arrange for care by someone else. I also know that University College London or the Royal National Orthopaedic Hospital Trust has the right to stop the study at any time, or to drop me from the study.

I have received a copy of this form.

Participant.

Name.....
Signature.....
Date.....

Investigator eliciting consent.

Name.....
Signature.....
Date.....

2.4 Participant information sheet – experienced user



RNOH Stanmore
Brockley Hill
Stanmore
Middlesex
HA7 4LP

Tel: 020 8954 2300
www.rnoh-stanmore.org.uk

**ROYAL FREE AND UNIVERSITY COLLEGE LONDON MEDICAL SCHOOL
ASPIRE CENTRE FOR DISABILITY SCIENCES
and
ROYAL NATIONAL ORTHOPAEDIC HOSPITAL TRUST
PARTICIPANT INFORMATION SHEET**

The purpose of this consent form is to provide you with the information that you need to consider in deciding whether to participate in a research study which will enable wheelchair users to assess their propulsion ability, achieve greater levels of mobility with less risk of injury.

Study title: Workshop for optimisation of wheelchair selection and user performance

Purpose of Research Project

Some wheelchair users report pain and loss of strength in their arms and shoulders after many years of manual wheelchair propulsion. These symptoms are consistent with repetitive strain injury produced during wheelchair propulsion and can affect the tendons, ligaments and joints of the arm and shoulder. In this study we plan to measure the forces generated during wheelchair propulsion and the metabolic energy cost for people with a recent spinal cord injury so that we can establish a protocol for the future to enable us to fit wheelchair more effectively and reduce the risk of injury resulting from long term wheelchair use. This protocol will compare a series of measurements obtained at the time you are provided with your first wheelchair and then over the next twelve months at 3 monthly intervals. We will also compare your measurements with similar wheelchair users with a much longer period of experience in using their wheelchair.

Procedure

We will ask you to propel two different wheelchairs in a number of test situations that our experienced users have suggested are representative of those found in everyday wheelchair use. These will include propulsion along a lino floor, a flat carpet, a ramp, a slope and set of wheelchair rollers. One wheelchair will be your own and the other will be a control chair carefully setup to match your body build, physical strength and level of spinal cord injury.

Men will be asked to remove their shirts and women will be provided with a vest. We will attach plastic markers with medical grade double-sided tape to the skin on your

arm and trunk. A camera system will be used to measure the position of the markers throughout these tests and will enable us to calculate the motion of your body, in particular arms trunk and shoulders during wheelchair propulsion.

We will fit you with a special face-mask attached to a collection device that you can wear or that will be attached to the back of your wheelchair. This will not interfere with your breathing in any way, but will allow us to measure how much oxygen you consume while propelling each wheelchair. We will also fit your wheelchair with a measurement device (Smartwheel) that will allow us to estimate the forces you produce when propelling your wheelchair.

Before each test we will attach a tether to your wheelchair so that we can pull it forward at speeds up to walking speed while measuring the rolling resistance of the wheelchair while you are sitting in the wheelchair.

If you decide to take part in this study, you will be invited to attend a full day assessment at the Royal National Orthopaedic Hospital. Your out of pocket expenses will be paid for by the project.

There are no expected risks associated with this study, other than those normally associated with wheelchair use. This study may produce a direct benefit to you now as an individual, and it could benefit you and many other wheelchair users in the future, as well as helping clinicians understand how to provide assessments that can have the greatest benefit in terms of optimum wheelchair propulsion, efficiency and reduce the risks of secondary injury resulting from long terms wheelchair use.

All information about you obtained during the study will be kept in files that will be kept confidential.

Taking part in this study is completely up to you. You can refuse to take part or withdraw from the study at any time and such a decision will not affect you care in any way.

If you have any questions, you can reach Professor Ferguson-Pell at 0208 909 5471 and he will do his best to answer them.

2.6 SmartWheel protocol

SmartWheel Protocol

Ensure the SmartWheel is fitted properly to the wheelchair – on the non-dominant side.

Fit the matching wheel to the opposite side.

Client transfers into the wheelchair.

As the SmartWheel records the data from the pushrim, it is important to inform the client to push using the pushrim only.

Make sure the test area is clear of obstructions.

Make sure wheelchair is in the starting position: castors facing rearwards.

Ask client to place hands in lap while the SmartWheel is switched on. It is important that nothing touches the pushrim of the SmartWheel while it automatically calibrates.

Lino protocol:

Instruct client to start pushing using the following script:

“This test is designed to see how you push on a smooth floor. When I tell you to ‘Go’ I want you to push your wheelchair in a straight line. Push at a comfortable speed, as if you were pushing on a path. Keep pushing until I tell you to stop. Do you have any questions?” Pause “Place your hands in your lap. GO”

Do not offer any encouragement to the client while they are pushing. After you stop the data collection, you may offer encouragement.

At the end of the run wait a few seconds before switching the SmartWheel off.

Repeat 3 times.

Slope protocol:

Instruct client to start pushing using the following script:

“This test is designed to see how you push up a ramp. When I tell you to ‘Go’ I want you to push your wheelchair up this ramp. Push at a comfortable speed. You may rest if needed. Do you have any questions?” Pause “Place your hands in your lap. GO”

Do not offer any encouragement to the client while they are pushing. After you stop the data collection, you may offer encouragement.

At the end of the run wait a few seconds before switching the SmartWheel off.

Repeat 3 times.

2.7 Considerations for the use of the SmartWheel.

Weight

The influence on test results of the weight of the SmartWheel should be given due considerations.

The SmartWheel itself weighs 4.9kg. A similar spoked wheel with solid tyre was found to weigh 1.7kg. The average weight of the users' own wheelchair in this study was 15.4kg. The additional 3.2kg not only constitute an increase in the mass that the user has to propel by 21% but also render the wheelchair unevenly balanced. It has been suggested in some studies to counterweight the opposite side. As some ultralight wheelchairs now weigh 10kg or less, counterweighting would nearly double the overall weight of the mass to be moved. The distributors of the SmartWheel no longer recommend counterweighting.

The concern over the weight of the SmartWheel influencing results has been discussed in the seating community from the outset, but no studies could be found which either supported or denied the contention that the heavier wheel makes a difference to performance.

Accuracy

In order to test the accuracy of the output from the SmartWheel, weights were attached to the SmartWheel and checked against the output. The weights applied were in increments of 1.9kg (18.64N) up to 7.6kg (74.56N). The weights themselves were checked on a weighing platform to ascertain their correct weight. As the SmartWheel samples very fast (240Hz), the test was only repeated once for a minimum of 15 sec and the average of all the sampled data used. The test was only carried out in one direction for each force (down for F_y , in for F_z , and forward for F_x).

As no calibration rig was available, the fixation of the SmartWheel had to be improvised. For the testing of the vertical force, F_y , the SmartWheel was clamped in the vertical position in a vice. The weights were applied to the lowest

point of the pushrim via a bracket. The results presented in Figure 36 show excellent correlation between the weight applied and the output.

For the test of the medial lateral force, F_z , the SmartWheel was fixed in the vice in the horizontal position. As weights were applied, it became increasingly difficult to stabilise the SmartWheel and stop it from tilting. The degree of tilt observed varied from 0.1° to 2.9° . The results presented in Figure 37 show the correlation between the weight applied and the output.

Testing for the horizontal force, F_x , proved to be very challenging and the variability in the results presented in Figure 38 is likely to be due more to the shortcomings in the test method than any unreliability in the SmartWheel.

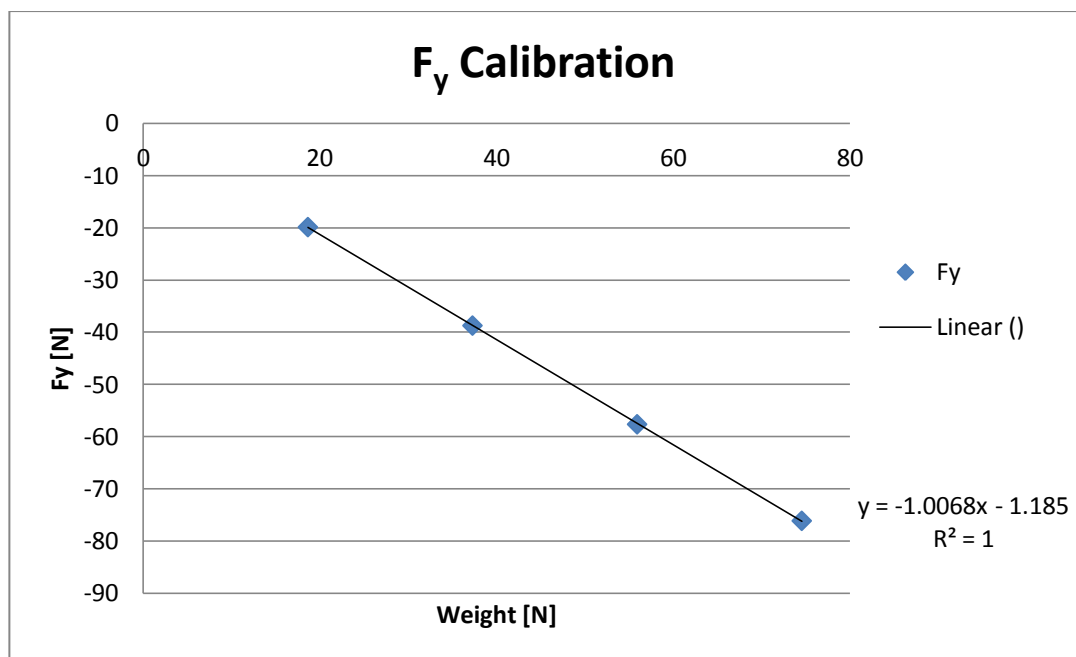


Figure 36 Results for accuracy of the SmartWheel calibration for the force F_y

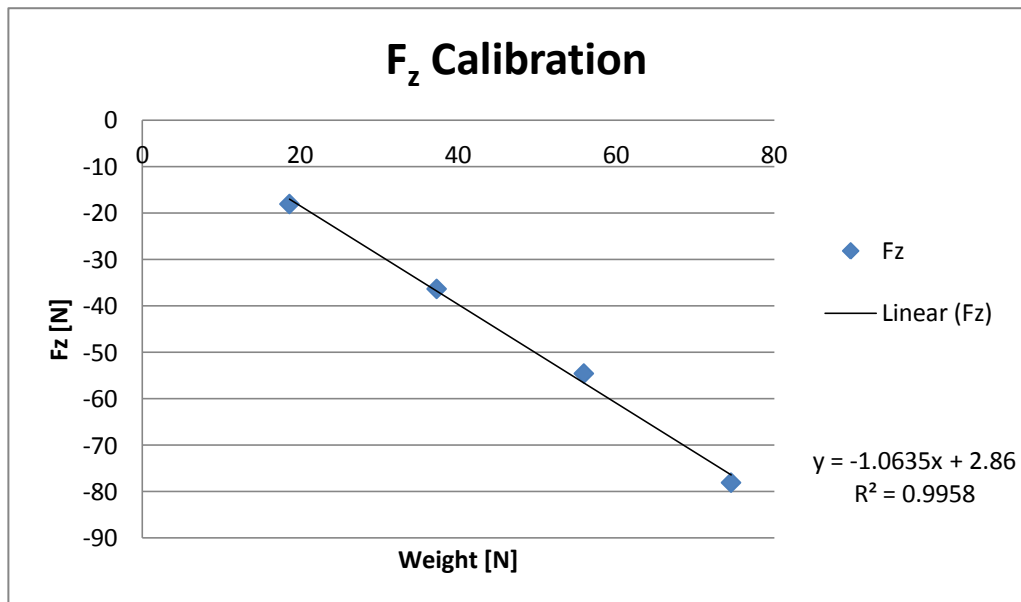


Figure 37 Results for accuracy of the SmartWheel for the force F_z

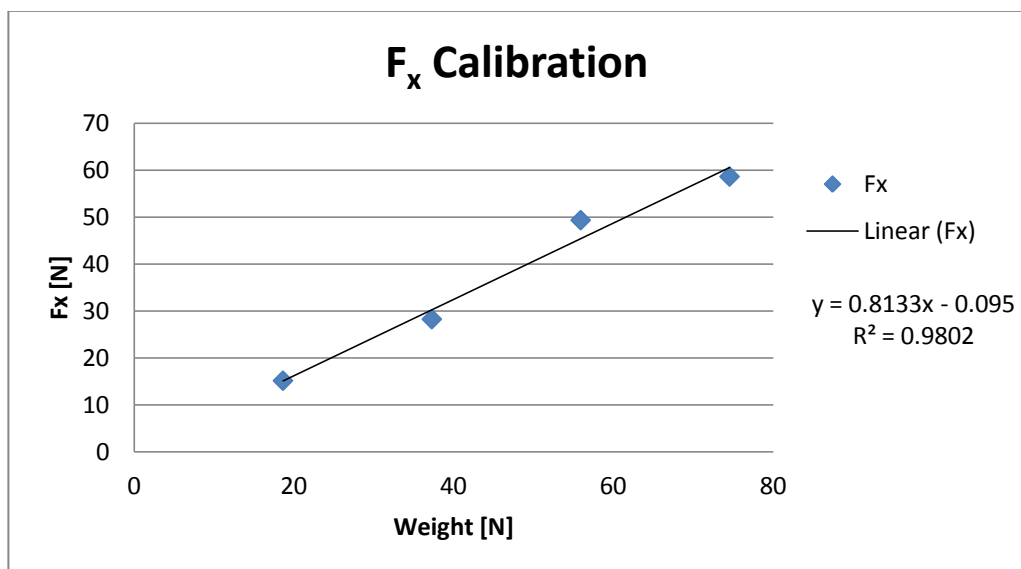


Figure 38 Results for accuracy of the SmartWheel for the force F_x

Weight normalisation of force

The revised SmartWheel protocol now recommends weight normalisation of force for both user and seating system weight.

Wheelchair configuration

The suggested clinical use of the SmartWheel is to assist the clinician in determining the most appropriate wheelchair prescription for an individual. In order to be able to compare propulsion results for one wheelchair with another, it is essential that the wheelchair configuration is documented appropriately. The revised SmartWheel report now allows the clinician to enter these details.

Pushrim propulsion

If using the SmartWheel for either research or clinical purposes it is important to realise the inherent limitation of the system for users with poor handfunction. These users are likely to require modifications to the pushrim on their own wheelchair to give better grip during propulsion. For the harder test of pushing up a ramp or slope many wheelchair users will automatically grip both tyre and pushrim for maximum grip. This practice would render the SmartWheel output meaningless.

2.8 Assessment form

WOWSUP Assessment Form.

Pre-assessment screening.

Name:

Address:

..... Postcode:

Tel. No: Mobile:

Date of birth: Date of injury:

Level: ASIA:

Height: Pre-injury weight:

GP: Surgery:

..... Tel. No.:

Consultant: Spinal Unit: RNOH SMH

Wheelchair Service Details.

Name of service:

Address:

..... Postcode:

Therapist:..... Tel. No:

Exclusion criteria (delete as appropriate):

UL pain on pushing Yes / No

Manual wheelchair user (min. all outdoor mobility) Yes / No

Wheelchair provided (not SIU chair) Yes / No

Transport required Yes / No

Date of screening: Date of first appointment:

Name of screening therapist: 188

Lifestyle Overview

To be completed on each assessment.

	Discharge	3 months	6 months	9 months	12 months
Date:					
Weight					
Housing					
Work					
Leisure					
Driving					

Key :

Housing: Return to Previous - 'PAA' Awaiting adaptations
'PAC' Adaptations completed

Housing: Discharge to Interim - 'IR' Awaiting re-housing
'IAA' Awaiting adaptations
Re-housed - 'R'

Occupation: 'PO' Return to: *previous occupation*

Occupation: 'NO' Return to: *new occupation*

'NR' No return

Leisure: Return to leisure activities - *insert hours/week.....hours*

Main leisure activity:

Driving: 'D' Driver 'P' Passenger

Chair into car – 'E' Easy 'D' Difficult 'VD' Very Difficult

Name: Date of assessment:

Wheelchair details

Own Wheelchair

Type:

Size (W x D):

Frame Type: Rigid

Folding

Funding: Private

Voucher

Wh.ch. serv.

Provision: Permanent

Interim

Review scheduled Y / N Date:

Rear Wheels: 22"

24"

26"

Tyres: Pneumatic

High pressure

Solid

Green

Correct pressure
(as psi on tyre)

Test Wheelchair

Type: *Quickie GPV*

Size (W x D):

Rigid

24"

Pneumatic

Correct pressure
(as psi on tyre)

Wheelchair details - cont.d

Own Wheelchair

Test Wheelchair

Rim type: Standard

 Plastic coated

 Foam grip

Standard √

Rim modified (describe):

Castors: 3"

 5"

 6"

 8"

5" √

Modifications made:(backrests/armrests)

.....

.....

Wheelchair Set-up

Own Wheelchair

Test Wheelchair

A - Front Seat Height: cm

A - Front Seat Height: cm

B - Rear Seat Height: cm

B - Rear Seat Height: cm

A-B = 'bucket':cm

A-B = 'bucket':cm

Finger tip to axle: cm above / below

Finger tip to axle: cm above / below

Back Rest Height: cm

Back Rest Height: cm

Back Rest Angle:°
(measured from the vertical)

Back Rest Angle:°
(measured from the vertical)

Name: Date of assessment:

Wheelchair Set-up

Own Wheelchair

Test Wheelchair

Footrest height:	Correct	<input type="checkbox"/>	Correct	<input type="checkbox"/>
	Too high	<input type="checkbox"/>		
	Too low	<input type="checkbox"/>		

Axle position – measured as distance between post. edge of back upright to center of axle. cm cm

Rear wheel camber:° Rear wheel camber:°

Comments:
.....
.....
.....

Wheelchair Stability

Weight on castors: kg Weight on rear wheels: kg

Static / dynamic stability - wheelchair skills level:

Ascending slope: Yes / No

Flicking castors onto mat: Yes / No

Static backwheel balance: Yes / No

Moving forwards in backwheel balance: Yes / No (***) Skill or stability?(***)

3 APPENDIX 3 – Shoulder pain

3.1 Wheelchair User's Shoulder Pain Index (WUSPI)

WHEELCHAIR USER'S SHOULDER PAIN INDEX (WUSPI)

Place a 'X' across the scale to estimate your level of pain with the following activities. Tick the box at right if the activity was not performed **in the past week**. Based on your experiences **IN THE PAST WEEK**, how much shoulder pain have you experienced when:

Not performed

- | | | |
|--|---------------|--|
| 1. Transferring from a bed to a wheelchair? | No pain _____ | Worst pain ever experienced <input type="checkbox"/> |
| 2. Transferring from a wheelchair to a car? | No pain _____ | Worst pain ever experienced <input type="checkbox"/> |
| 3. Transferring from a wheelchair to a bath or shower? | No pain _____ | Worst pain ever experienced <input type="checkbox"/> |
| 4. Loading your wheelchair into a car? | No pain _____ | Worst pain ever experienced <input type="checkbox"/> |
| 5. Pushing your wheelchair for 10 minutes or more? | No pain _____ | Worst pain ever experienced <input type="checkbox"/> |
| 6. Pushing up ramps or inclines outdoors? | No pain _____ | Worst pain ever experienced <input type="checkbox"/> |
| 7. Lifting objects down from an overhead shelf? | No pain _____ | Worst pain ever experienced <input type="checkbox"/> |
| 8. Putting on trousers? | No pain _____ | Worst pain ever experienced <input type="checkbox"/> |
| 9. Putting on a t-shirt or a jumper? | No pain _____ | Worst pain ever experienced <input type="checkbox"/> |
| 10. Putting on a button down shirt? | No pain _____ | Worst pain ever experienced <input type="checkbox"/> |
| 11. Washing your back? | No pain _____ | Worst pain ever experienced <input type="checkbox"/> |
| 12. Usual daily activities | No pain _____ | Worst pain ever experienced <input type="checkbox"/> |
| 13. Driving? | No pain _____ | Worst pain ever experienced <input type="checkbox"/> |
| 14. Performing household chores? | No pain _____ | Worst pain ever experienced <input type="checkbox"/> |
| 15. Sleeping? | No pain _____ | Worst pain ever experienced <input type="checkbox"/> |

Adapted from original (Wheelchair User's Shoulder Pain Index (WUSPI), 1995) and reproduced in its adapted form with permission of the author, Kathleen A. Curtis, PT, Ph.D.

4 APPENDIX 4 - Abbreviations and Definitions

4.1 Abbreviations

ADL	Activities of Daily Living
AIS	ASIA Impairment Scale
	<p>A = Complete. No sensory or motor function is preserved in the sacral segments S4-S5.</p> <p>B = Sensory Incomplete. Sensory but not motor function is preserved below the neurological level and includes the sacral segments S4-S5 (light touch, pin prick at S4-S5: or deep anal pressure (DAP)), AND no motor function is preserved more than three levels below the motor level on either side of the body.</p> <p>C = Motor Incomplete. Motor function is preserved below the neurological level, and more than half of key muscle functions below the single neurological level of injury (NLI) have a muscle grade less than 3 (Grades 0-2).</p> <p>D = Motor Incomplete. Motor function is preserved below the neurological level, and at least half (half or more) of key muscle functions below the NLI have a muscle grade > 3.</p> <p>E = Normal. If sensation and motor function as tested with the ISNCSCI are graded as normal in all segments, and the patient had prior deficits, then the AIS grade is E. Someone without an initial SCI does not receive an AIS grade.</p>
ASIA	American Spinal Injury Association
BASCIS	British Association of Spinal Injury Specialists
BMI	Body Mass Index

B.W.B	Back-wheel-balance
CHART	Craig Handicap Assessment and Reporting Technique
CTS	Carpal Tunnel Syndrome
DHSS	Department of Health and Social Services
FIM	Functional Independence Measure
LSCIC	London Spinal Cord Injury Centre
MASCIP	Multidisciplinary Association of Spinal Cord Injury
MRI	Magnetic Resonance Imaging
MWU	Manual wheelchair user
NHS	National Health Service
NSIC	National Spinal Injuries Centre
QALY	Quality-Adjusted Life-Year
RCT	Rotator Cuff Tear
ROM	Range of Movement
SCI	Spinal Cord Injury
SCIC	Spinal Cord Injury Centre
SIA	Spinal Injuries Association
TSCI	Traumatic spinal cord injury
VAS	Visual Analogue Scale
WUSPI	Wheelchair User's Shoulder Pain Index

4.2 Definitions

Tetraplegia	SCI to the cervical spine. Upper limb function as well as trunk and lower limb function will be affected.
Tetraplegic	Person with Tetraplegia
Paraplegia	SCI to the thoracic or lumbar spine. Trunk and lower limbs will be affected.
Paraplegic	Person with Paraplegia
Complete	No recovery (sensory or motor) below the level of the lesion.
Incomplete	Some degree of recovery (sensory or motor) below the level of the lesion.
Full-time user	Needing a wheelchair for all mobility needs, both in- and outdoors
Folding frame	Wheelchair with standard cross brace design of frame
Rigid frame	Wheelchair of box frame design
Minimally adjustable	A wheelchair with only a few positions whereby the rear axle can be placed forward of the back upright or up and down in relation to the seat. No ability to camber the rear wheel.
Multi-adjustable	A wheelchair with a range of options for the rear axle to be moved forward as well as up or down in relation to the seat. The rear wheel can be cambered.
Custom-made	Bespoke wheelchair – usually the angle of the seat in relation to the backrest, the height of the seat within the wheels and backrest height are all fixed at

the point of manufacture to the individual's specification.

Rear wheel position can usually be adjusted in a forward direction.

Degree of camber is typically fixed at point of manufacture.

Back-wheel-balance	The ability to balance on the rear wheels of the wheelchair by tipping the wheelchair backwards and lifting the front castors off the ground.
'Wheelie'	'To pop a wheelie' = back-wheel-balance
'Pushability'	the effort involved in propelling the wheelchair
'Interim provision'	Wheelchair supplied for short-term use only
'First provision'	Wheelchair provided as first long-term wheelchair
'Present provision'	Wheelchair used at the time of the survey
Standard wheelchair	weight > 16 kg (35 lbs)
Lightweight wheelchair	weight 11.4kg – 16 kg (25-35lbs)
Ultralight wheelchair	< 11.4.kg (25 lbs)

5 APPENDIX 5 Useful contacts

5.1 Manufacturers

Sunrise Medical	www.sunrisemedical.co.uk
Invacare UK	www.invacare.co.uk
Three Rivers Holdings	http://3rivers.com/
Etac Wheelchairs	www.etac.com
Kuschall Wheelchairs	www.kuschall-uk.co.uk
Panthera Wheelchairs	www.panthera.se