CLINICAL RESEARCH SUMMARY

TiLite is dedicated to improving the mobility of manual wheelchair users. We recognize that justifying the need for high quality wheelchairs can be a difficult and time-consuming task for health care practitioners. Also, we are aware that funding sources often are reluctant to pay for high quality wheelchairs without evidence-based research demonstrating that the benefits justify the cost.

Fortunately, over the past 10 years a substantial body of peer-reviewed evidence has been published that clearly justifies high-end rehab equipment such as TiLite wheelchairs. To assist you, we have prepared this document to summarize the relevant peer-reviewed evidence in one convenient location. We will update this document periodically as new research becomes available. This document can be downloaded from our website at www.tilite.com. If you have questions, please contact Richard Forman at 800-545-2266, ext. 238, or at rforman@tilite.com.

Part I: Introduction

Scientific studies conclusively demonstrate that long-term manual wheelchair users suffer from upper limb pain and repetitive strain injuries in their upper limbs (see Part II below). Other scientific studies prove that such pain and injuries adversely affect the physical health of manual wheelchair users and increase their health care and related costs (see Part III below) and their mental health and ability to reintegrate into society (see Part VIII below). Studies also prove that manual wheelchair users experience vibration levels during propulsion that exceed ISO standards (see Part IV below). Studies have determined that typical manual wheelchair users self-propel several thousand strokes per day (see Part VI below). Finally, studies have proven that ultralightweight wheelchairs, especially titanium wheelchairs, provide the best value (in terms of fatigue life per dollar) and reduced downtime (see Part VII below). As a result, the scientific studies have concluded that the critical factors in wheelchair prescription are: (1) reducing wheelchair weight as much as possible and (2) providing made-to-measure wheelchairs, because these two factors combine to minimize the frequency of nonessential repetitive upper limb tasks and the force required to complete those tasks (see Part V below). For a more complete discussion regarding these conclusions, readers of this Survey should obtain a copy of Preservation of Upper Limb Function Following Spinal Cord Injury: A Clinical Practice Guideline for Health-Care Professionals published by the Consortium for Spinal Cord Medicine and available at the Paralyzed Veterans of America website at http://www.pva.org/site/DocServer/upperlimb.pdf?docID=705. This Clinical Practice Guideline is one of the most comprehensive research tools available to rehab health care professionals.

Part II: Studies Prove that Long-Term Manual Wheelchair Users Suffer from Upper Limb Pain and Repetitive Strain Injuries

- Surveys involving as many as 450 wheelchair-based individuals find that as many as 73% report some degree of chronic upper-extremity pain, which they attribute primarily to wheelchair propulsion and transfers.[1]

- There is a time relationship between injury and upper extremity complaints—during the first 5 years, 52% of patients complained of pain, which increased to 62% by 10 years, 72% by 15 years and 100% by 20 years.[2]

- The incidence of carpal tunnel syndrome (CTS) among manual wheelchair users ranges from 40% to 66%, making carpal tunnel syndrome the most common neurologic cause of upper-extremity pain for manual wheelchair users.[3]

- The incidence of shoulder pain among manual wheelchair users ranges from 30% to 60%[4], and 65% of individuals with paraplegia and shoulder pain were found to have rotator cuff tears.[5] Length of time since SCI onset increases the likelihood of shoulder pain, and, as compared to people without shoulder pain, people with such pain were more likely to report shoulder range of motion problems, have lower Craig Handicap Assessment Reporting Technique scores and rate their health as fair.[6]

- The incidence of shoulder pain in acute tetraplegia has been reported to range from 51% to 78%.[7] Quantitative strength testing revealed that subjects with tetraplegia have less strength in the critical rotator cuff muscle groups than do persons with paraplegia.[8] Early limb loading with high superior force has been noted in the push phase in tetraplegia wheelchair propulsion, which may compress subacromial structures, especially with the humerus in abduction and internal rotation.[9]

- Sixty six percent (66%) of wheelchair users report developing neck pain since becoming a wheelchair user.[10]

- The incidence of elbow pain among manual wheelchair users ranges from 5% to 16%.[11]

WHY TILITE? TiLite wheelchairs are designed by engineers who use wheelchairs. As a result, TiLite has always known what the above studies now prove, and TiLite has always designed its wheelchairs to be as light and custom-fitted as state-of-the-art design and production technology will allow. As a result, TiLite wheelchairs weigh less and fit better, which leads to less upper limb injury and pain among manual wheelchair users.

Part III: Studies Prove that Upper Limb Pain Adversely Affects the Health of Wheelchair Users and Increases Health Care and Related Costs

- Upper limb pain is associated with lower quality of life and increased dependence on helpers.[12] In fact, pain was found to be the only factor that correlated with lower quality of life scores.[13] Of individuals experiencing upper limb pain, 26% required additional help with functional activities and 28% reported limitations on independence.[14] Loss of independence may have a detrimental psychological effect.[15]

- Limitations related to mobility can become crucial, adversely affecting ability to participate in nearly all activities of daily living,[16] and quality of life and perception of life satisfaction.[17]

- Upper limb pain has been found to be a major reason for functional decline in individuals with spinal cord injury who required more physical assistance since their injury.[18]

- Loss of independence may have financial consequences (e.g., the need to employ caregivers and/or to purchase additional equipment) and it increases the physical burden on caregivers. Shoulder pain may therefore be functionally and economically equivalent to a higher lesion level.[19]

- There is a significant association between employment status and upper limb pain – unemployment is higher (21.4% versus 7.1%) and full-time employment is lower (20% versus 45.2%) in persons with upper limb pain when compared to those without such pain.[20]

WHY TILITE? TiLite wheelchairs are designed by wheelchair users to live active, independent lifestyles. TiLite wheelchairs are designed to help wheelchair users remain active and independent longer than would otherwise be possible in heavier, less well-fitting wheelchairs.

Part IV: Studies Prove that Manual Wheelchair Users are Exposed to Unhealthy Levels of Vibration

- When self-propelling, bumps, curbs and driving surfaces cause vibrations on the wheelchair and, in turn, the wheelchair user. ISO and ANSI have developed a standard for whole-body vibration measurement and the risks associated therewith. Research has shown that wheelchair propulsion produces vibration loads that exceed the ISO 2631-1 standards at the seat of the wheelchair and at the head of the wheelchair user.[21]

- Long-term wheelchair use may lead to secondary injuries as a result of exposure to shock and vibration.[22]

- Rear suspension wheelchair systems reduce some of the factors related to shock and vibration exposure, but they are not clearly superior to traditional wheelchair designs.[23]

- Wheelchair ride comfort may influence pain, pelvic/spinal deformity development and technology abandonment, and testing shows that users rate ultralight wheelchairs higher than lightweight wheelchairs for both ride comfort and ergonomics.[24]

WHY TILITE? Most metals vibrate. Titanium absorbs vibration. As a result, manual wheelchair users will experience a smoother, lower vibration ride if their wheelchair frames are made with titanium than they would in wheelchair frames made from aluminum or steel. Many wheelchair users, especially those with spinal cord injury, report that simply switching from aluminum to titanium has dramatically reduced the amount of vibration-related pain and stress that they experience on a daily basis.

Part V: Studies Prove that Reducing Wheelchair Weight and Providing Made-to-Measure Wheelchairs Helps to Minimize the Frequency of Nonessential Repetitive Upper Limb Tasks and the Force Required to Complete those Tasks, which are Essential Requirements to Reducing Upper Limb Injury and Pain as a Result of Manual Wheelchair Propulsion

- During wheelchair propulsion, forces on the pushrim act equally and opposite on the user's limb and are transmitted up through the arm and shoulder joints, and repetitive application of large upward forces has been implicated as a cause of shoulder pain and injury.[25]

- Increasing propulsion frequency and a higher rate of rise of total pushrim forces correlate with increased median nerve dysfunction, and median nerve injury is the basic pathology behind the development of CTS.[26]

- Wheelchair users who self-propel with a greater range of motion show better nerve function and use less force and fewer strokes to self-propel than users who self-propel with a smaller range of motion.[27]

- Providing wheelchair users with adjustable axle position and then fitting the user to the wheelchair can improve propulsion biomechanics and likely reduce the risk of upper limb injuries.[28] A more forward axle position decreases rolling resistance and increases propulsion efficiency.[29]

- Individuals who propel with a greater percentage of force directed toward the axle are at increased risk of progression of shoulder joint MRI findings over time, and reducing radial forces to below 5% of body weight during wheelchair propulsion may minimize the likelihood of developing new or progressive shoulder injuries.[30]

- Ultralight wheelchairs require less effort to propel, thus placing less strain on the upper extremities. This reduced effort is due in part to the chair's weight and in part to the use of high-quality components for parts, such as bearings and casters, and are constructed to higher tolerances.[31]

- In a study comparing a 27-lb ultralightweight wheelchair to a 44-lb standard wheelchair, subjects with paraplegia were able to self-propel farther at increased speed and use less oxygen. Subjects with tetraplegia also were able to self-propel farther at increased speed.[32]

- It has been established that there is a correlation between forward head positioning and shoulder pain.[33] Therefore, wheelchair prescription must do more than provide a mobility device. The orthotic posture-supporting properties of the wheelchair must be recognized and wheelchairs must be specifically prescribed and adjusted to meet the needs of the user.[34]

- Ultralight wheelchairs are rated to be more comfortable during propulsion and had better basic ergonomics than lightweight wheelchairs.[35]

WHY TILITE? By making its frames out of titanium instead of aluminum or steel, TiLite has selected a metal that is both lighter and stronger than these competing materials. As a result, every TiLite wheelchair is lighter than any comparably designed and configured wheelchair made with aluminum or steel. Most TiLite wheelchairs are also "made-to-measure", thereby ensuring the best fit possible. Therefore, TiLite wheelchairs achieve what the studies prove is desirable—reducing weight as much as possible and ensuring the best fit possible—thereby reducing the overall effort necessary to self propel and transport the wheelchair.

Part VI: Studies Prove that Wheelchair Users Self-Propel a Large Number of Times each Day

- Manual wheelchair users generally travel approximately 3.5 km/day in their wheelchairs.[36]

- The average manual wheelchair user is self-propels 3500 strokes per day, so even small differences in forces at the pushrim can lead to significantly greater risk of injury.[37]

WHY TILITE? If the typical TiLite wheelchair weighs 5 lbs less than a comparably designed and equipped aluminum wheelchair, then the average manual wheelchair user will reduce his daily pushing requirement by 3,500 multiplied by 5 lbs, or 16,500 lbs per day. That is more than 8 tons per day and more than 6 million lbs per year! Anyone who believes that 5 lbs doesn't matter can't do math.

Part VII: Ultralight Wheelchairs, Especially Titanium Wheelchairs, Provide the Best Value to the User and the Reimbursement Source

- In comparison fatigue testing to ANSI/RESNA standards, ultralight wheelchairs were half as likely to experience a Class III failure (a total failure of the chair) as compared with lightweight wheelchairs, and all of the ultralightweight wheelchairs that failed had aluminum frames—no titanium frames experienced a Class III failure. In addition, the ultralight wheelchairs had a significantly longer fatigue life than lightweight wheelchairs (1,009,108 cycles versus 187,370 cycles) and were 2.3 times more cost-effective in terms of dollars per life cycle.[38]

- The fatigue life for the ultralight wheelchairs averaged 1,009,108 cycles versus 187,370 cycles for lightweight wheelchairs, which means that the ultralight wheelchairs last about 5.4 times longer than lightweight wheelchairs. Another way of looking at this is that the average ultralight endured 807 kilometers of rolling road testing before failure versus 150 kilometers for the average lightweight wheelchair. In terms of value, the ultralight wheelchairs had an average value of 673 cycles per dollar as compared with 210 cycles per dollar for the lightweight wheelchairs. Therefore, it is more cost-effective and most appropriate to provide long-term wheelchair users with ultralight wheelchairs than lightweight wheelchairs.[39]

- The inclusion of suspension elements did not significantly improve wheelchair fatigue life, and in some cases the modifications reduced the total number of equivalent cycles. Furthermore, the increased cost considerably lowered their value in relation to the other types of wheelchairs.[40]

WHY TILITE? While the studies cited above did not specifically address titanium compared to aluminum, it was noted that none of the titanium wheelchairs experience a class III failure—a failure that rendered the wheelchair unusable. There are several reasons why titanium wheelchairs are more durable than wheelchairs made from aluminum or steel. First, by absorbing more vibration, the non-titanium components are exposed to less vibration and are less likely to come loose. Second, because titanium, unlike steel or aluminum, does not experience work-fatigue, the frame will not become brittle over time and will be less likely to break as a result. Third, because most TiLite wheelchairs are made-to-measure, TiLite wheelchairs reduce the number of adjustable components, thereby reducing the number of places where a failure can occur. Fourth, because titanium will not corrode or rust, TiLite wheelchair frames will not become weakened by rust or corrosion.

Part VIII: Providing the Proper Wheelchair Affects the Mental Health of the Wheelchair User and His or Her Ability to Reintegrate into Society

- The wheelchair is the most commonly cited factor limiting participation in activities in the home, in the community and during transportation. Providing a wheelchair that fits well and is simple to operate without addressing environmental access may limit the potential benefits of the equipment. Similarly, an accessible environment is of no benefit if the equipment is difficult for the user to operate.[41]

- Providing appropriate wheelchairs with design features that are customized to the users' environment, needs and preference is an important part of successful rehabilitation.[42]

- The ability of people with spinal cord injury to reintegrate into society and regain independence depends much on access to appropriate and adequate assistive technology, such as wheelchairs.[43]

WHY TILITE? Because TiLite wheelchairs are lighter and better performing, they permit their users to be more active and independent. This, in turn benefits their mental health and well-being. Also, because TiLite wheelchairs are designed fit the bodies of their users more closely, TiLite wheelchairs are less noticeable than many other wheelchairs, thereby giving wheelchair users the confidence to live more active and independent lives.

Part IX: Why TiLite?

Our Philosophy. TiLite evolved from the simple idea of developing a superior class of manual wheelchairs that would combine orthoses-like customization with the most advanced materials. We felt that these attributes would help users remain independent longer, experience reduced body stress, and incur fewer posture-related problems. TiLite is the only wheelchair company that is obsessively dedicated to improving the mobility of wheelchair users. The result is a line of adult, pediatric and sport titanium wheelchairs that are truly 21st century wheeled orthoses.

Light Weight Titanium. Most metals are heavy or weak. Titanium is light and strong. In fact, TiLite titanium is 50% lighter than steel and twice the strength of 6061 aluminum. This means TiLite wheelchair frames can be half the weight of aluminum frames without sacrificing strength. Therefore, TiLite wheelchairs weigh less, resulting in reduced joint stress and increased portability. At the same time, titanium's superior strength ensure that TiLite wheelchairs will keep rolling long into the future. The extremely high strength-to-weight ratio of aerospace-grade Titanium enables the design of products that weigh less than 20 lbs, versus aluminum and steel chairs weighing from 25 to 50+ lbs. Titanium is the only metal with this unique combination of attributes.

Vibration Reduction. Most metals vibrate. Titanium absorbs vibration. Titanium wheelchairs transmit less vibration than aluminum or steel, thus reducing vibrational stresses transmitted to the wheelchair user.

Superior Durability. Most metals rust, corrode or get brittle over time. Titanium doesn't. Therefore, titanium wheelchairs are significantly more durable than chairs made from aluminum or steel. This means that the smooth, vibration-free ride and durability of TiLite wheelchairs will last forever. Literally, it will last forever.

Custom. TiLite wheelchairs are designed by engineers who use wheelchairs. Each TiLite wheelchair is hand crafted to the user's unique dimensions–just like a custom-made orthotic device. Therapists can prescribe a TiLite wheelchair with confidence, knowing that the likelihood of a successful outcome of the rehab process will be enhanced through the properly fit and manufactured TiLite wheelchair. Design input is also critical to the increased functionality of TiLite products. Feedback and design criteria come from customer and therapist suggestions, which help make TiLite wheelchairs the brand of choice by wheelchair users throughout the world.

Quality. TiLite has more than 15 years' experience manufacturing titanium wheelchairs. We set no limits on TiLite quality. TiLite meticulously hand crafts each TiLite wheelchair. This requires that we constantly put our own methods to the test and make critical appraisals of our own work. For TiLite this voluntary self-monitoring is essential for our products and our production methods to remain state of the art.

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