RESNA Position on the Application of Tilt, Recline, and Elevating Leg Rests for Wheelchairs

Literature Update 2023

Rehabilitation Engineering & Assistive Technology Society of North America

2001 K Street NW, 3rd Floor North

Washington, DC 20006-1072

(202) 367-1121

www.resna.org

Approved by the RESNA Board of Directors on February 26th, 2025

Authors:

Jillian Kenderish, MOTR/L, ATP/SMS

Magee Rehabilitation Hospital

Jefferson Health Systems

Tabatha James, ATP/SMS, OTR

Numotion

Rebecca Russell, PT, DPT, ATP

UPMC Center for Assistive Technology

Heather Cianciolo OTR/L, ATP/SMS

Regional Clinical Education Manager

Permobil Americas

Jennith Bernstein, PT, DPT, ATP/SMS

Clinical Affairs Manager

Permobil

Grace Denfeld, OTR/L

The Afya Foundation of America

TABLE OF CONTENTS

ix. Quality of Life and Participation in Activities of Daily Living (ADLs)

x. Summary

c) Limitations of the Current Literature

d) Case Study

e) Issues Related to Practice, Policy, and Research

5) Triggers of New Findings that Would Require an Update of the Position

6) Relation of this Position Paper to the other Position Papers

7) Summary of the Position Paper Development

8) References

9) Appendix

About This Paper

This is an official RESNA Position Paper on Clinical and Professional Practice. As such, it has been prepared in accordance with the specific guidelines and approval process defined by the RESNA Board of Directors for Position Papers. See http://www.resna.org/knowledge-center/position-papers-white-papers-and-provisionguides for a complete description of this procedure. Key aspects of this procedure include:

1. Establishment of a Working Group of three or more experts to author the paper, using evidence from the published literature, documented best practices, and other input from experts in the field as the basis for the content.
2. Review of the draft by at least two subject matter experts from the relevant RESNA SIG or PSG, as well as all interested SIG or PSG members, and subsequent revisions.
3. Circulation of the revised draft to RESNA members and others for a 60-day public comment period, and subsequent revisions.
4. Review of the revised draft by the RESNA Board of Directors, and subsequent revisions.
5. Final approval of the paper by the RESNA Board of Directors

RESNA Position on the Application of Tilt, Recline, and Elevating Leg Rests for Wheelchairs: Literature Update 2023

Introduction

This RESNA Position paper synthesizes current literature to guide practitioners in decision-making and use of seat functions for individuals who require customized mobility devices. The information herein provides guidance on the utility of seat functions available on manual and power wheelchairs for the clinical practice of Seating and Wheeled Mobility (SWM). This Position is intended to supplement clinical judgment in all areas of clinical practice that service adult, adolescent, and pediatric populations with mobility-related impairments.

This RESNA Position is an official statement intended to inform clinicians, consumers, and industry stakeholders of best evidence-based practices and to inform policy decisions regarding Assistive Technology (AT) devices, including Complex Rehabilitation Technology (CRT), for wheelchair service delivery. The global research and publications reviewed for this update revealed high quality evidence and valuable insights for the individual user, funding sources, and serves as a guide for understanding and expansion of policies related to wheelchair provision, usage, and accessibility. The evidence-based outcomes and interventions discussed in this update further confirms the medical and functional necessity of AT devices, ensuring that individuals with disabilities receive appropriate, equitable and effective healthcare service delivery.

Statement of Position

The Position:

Activities of daily living (ADLs), instrumental activities of daily living (IADLs), and mobility-related activities of daily living (MRADLs) are important for maintaining function and community access for individuals who manage mobility-related impairments (Guo & Sapra, 2022). ADLs are basic self-care tasks such as dressing, toileting, eating, grooming, and bathing, while IADLs include more complex activities like managing finances, cooking, and transportation. Mobility-related impairments can challenge the ability to perform these tasks safely and independently and can significantly impact quality of life when ability is compromised, strongly driving the need for assistive technology and CRT.

This 2023 Position builds on prior works and clinical consensus statements by Dicianno et al., (2009) and Dicianno et al., (2015) to update RESNA's Position on the clinical application of tilt, recline, and elevating leg rests. RESNA asserts that these functions are medically necessary for disease management, safety, and overall function, in areas that include but are not limited to:

- Improved transfer safety and biomechanics
- Postural realignment and corrective or accommodated positioning
- Postural support for access to tilt and independent propulsion
- Improved physiological functioning
- Pressure redistribution and tissue perfusion
- Improved pain management and comfort, decreased fatigue
- Sitting tolerance and participation
- Quality of Life (QOL) and performance of Mobility Related Activities of Daily Living (MRADLs)

This Position statement from RESNA encourages informed application of seat function prescription and use to mitigate potential risks and ensure positive health outcomes (Arledge et al., 2011). This RESNA Position recommends that Licensed Clinical Medical Professionals (LCMP), such as Physicians, Physician Assistants, Physiatrists, Nurse Practitioners, Clinical Nurse Specialists, Occupational and Physical Therapists be involved in all evaluations to minimize risks of adverse events and promote quality outcomes. In accordance with the RESNA Wheelchair Service Provision Guidelines, it is specified that clinicians may hold either the Assistive Technology Professional (ATP) or Seating and Mobility Specialist (SMS) distinction, as recognized by RESNA. Additionally, equipment suppliers are mandated to possess at least one of these distinctions.

Stakeholders, including consumers, caregivers, and the interdisciplinary team, are urged to engage in each stage of the service delivery process, from prescription and assessments to trials, delivery, and training. This holistic involvement facilitates the demonstration and documentation of improvements through pre- and post-objective data collection methods to fully understand the individual and global benefit of equipment provision. These methods include digital photography (as permitted), wheelchair skills testing (e.g., propulsion analysis, operational performance), and pressure analyses (Arledge et al., 2011), and other relevant measures advised by the clinical team.

Given the scope of research methods utilized, and populations included in the literature used to inform the conclusions listed in this paper, clinicians should be aware of the need to evaluate the clinical utility of each study if using them to inform individualized treatment plans or discharge recommendations. Factors to consider should include, but are not limited to, the size of the study, research methods, and the presence or absence of specific disabilities or conditions.

Populations and Subpopulations Affected

Updated policies and research regarding seat functions for wheelchairs can impact a wide range of populations and subpopulations, including, but not limited to:

- Individuals with disabilities
- Individuals aging with and into a disability
- Pediatric populations with disabilities and/or mobility limitations
- Maternal and child health
- Occupational and Physical Therapy, and Speech Language Pathology practitioners
- Manufacturers of CRT, AT, and Durable Medical Equipment (DME)
- Long Term Care Facilities, Assisted Living Facilities, group homes, and other community-based care homes
- Stakeholders responsible for insurance policy, coverage, coding, and reimbursement for wheelchair-related expenses
- Consumer advocacy groups
- Public health organizations and government agencies
- Educational institutions and related AT curriculums
- Urban planners and accessible public spaces

Clinical Contraindications

Clinicians make evidence-based decisions on when to use manual or power seat function interventions based on individual need and presentation. While some textbook solutions may be effective, complex care requires clinical consideration of a client-specific needs and response to intervention, along with scientific findings. This RESNA Position asserts that dual consideration

be given to each individual to lessen risk; generalizing scientific research for individuals with complex clinical needs increases vulnerability for individuals who may not be represented in existing literature.

The following clinical contraindications for the use of seat functions were discussed within Dicianno et al., (2009) and Dicianno et al., (2015), and remain relevant. Examples previously cited include backflow of urine with indwelling catheters, which can happen when using tilt, or tilt and recline; tissue shearing and stress on the hip joints when using recline only to change the seat-to-back angle; reflex spasticity and pain with angles of elevating leg rests and/or use of recline for individuals with joint limitations or variations in muscle tone.

The authors of this RESNA Position encourage caution but not necessarily exclusion of seat function use for individuals with non-integrated reflexes (such as righting reflex, asymmetrical and symmetrical tonic neck reflex), spasticity, and/or fluctuating tone. These individuals require seating and seat function interventions different from individuals with integrated reflexes, and normal voluntary muscle tone. Per De Souza & Frank (2020), spasticity is indicated as problematic when it interferes with stability in the chair. Seating instability, when not properly supported, poses an increased risk of contractures, pressure injuries, and musculoskeletal deformations and related dysfunction (De Souza & Frank, 2020).

For individuals who require custom molded seating, manual and power recline should be individually considered as it creates displacement from the mold contours and may lead to friction and shear that could create skin breakdown.

For individuals using combinations of tilt and recline, it is important to assess whether the individual has the upper extremity strength and range of motion to operate the seat functions

against gravity, or if placement of controls or switches can maintain independent access to mobility and positioning (Titus & Polgar, 2021); this particular contraindication urges consideration of manual versus power seat function access, and whether manual or power tilt or recline should be accessible to the user, and/or their caregivers via attendant controls.

Additionally, functional positioning should prioritize optimal physiological functions of the sympathetic and parasympathetic nervous systems. In these instances, the various combinations of tilt, recline and leg elevation must be clinically directed by the LCMP's and programmed by the ATP such that excess mechanical and gravitational forces are not placed on the user that could cause pain, pressure injuries, autonomic dysreflexia, respiratory distress, or other system compromise.

Lastly, anterior tilt on manual and power wheelchairs has become an available intervention since the previous RESNA Position. Some manufacturers now offer seating systems capable of up to 30 degrees of anterior tilt to facilitate standing, transfers, and functional reaching; secondary anterior supports should be individually considered with use of this function to maintain positioning in the chair and safety during use. Clinicians should consider whether greater degrees of anterior tilt will cause instability of the trunk or loss of balance as an individual’s mass moves anterior to their center of gravity, and out of their base of support.

This RESNA Position asserts that manual and power seat functions should not be individually or blanketly excluded if they are clinically justified, trialed, and used as recommended under the guidance of the clinical team. Tilt, recline, leg elevation and their ancillary capabilities play a valuable role in prevention, safety, and function for medically complex individuals with specific mobility challenges.

Relevance of Position

RESNA and Constituencies

RESNA is the leading professional organization dedicated to enhancing the well-being of individuals with disabilities through improved access to technology solutions and plays a vital role in advancing seating and wheeled mobility practice. Through certification programs, continuing education, and professional development opportunities, RESNA ensures that SWM practitioners, providers, individuals with disabilities, and their advocates are equipped with the knowledge and skills necessary to deliver and receive high-quality services.

RESNA's commitment to developing assistive technology standards, advocating for research and public policy, and facilitating innovation and information exchange underscores its dedication to addressing the diverse needs of a multidisciplinary constituency. As a 501(c)(3) not-for-profit membership association, RESNA's overarching goal is to maximize the health and well-being of people with disabilities through technology. By supporting scientific, literary, professional, and educational activities, RESNA contributes to the public welfare and strives to maximize quality of life for all citizens.

Aligned with RESNA's mission, this 2023 RESNA Position Paper serves as an essential resource for SWM practitioners, providers, individuals with disabilities, and their advocates. By promoting evidence-based practices and fostering collaboration, RESNA demonstrates its commitment to enhancing outcomes for those with mobility-related impairments.

Significance to Society

This Position can be used to guide clinical and consumer education on the use of seat functions, improve general knowledge of wheelchairs and their medical benefits, and inform

advocacy efforts. Additionally, it has the potential to shape global public health policies, including but not limited to the following areas:

- Accessibility and inclusion
- Prevention of secondary health complications and comorbidities
- Improved quality of life
- Independence and self-actualization
- Reduction in individual and system-level healthcare costs
- Establishment of global standards and accessibility
- Promotion of public awareness and advocacy
- Capacity building and training for professionals and caregivers
- Continued support for research and innovation
- Greater global collaboration and continuity of care

Rationale for the Position

Definitions

To ensure clarity for all readers, key terms are defined as follows:

Tilt and Tilt-in-Space: **Center of gravity tilt** operates anteriorly and posteriorly and is available as a seat function on manual and power wheelchairs. This tilt is considered a rotational tilt, as it rotates forward or backward around the center axle beneath the user's body mass. The tilt movement occurs primarily in the sagittal plane and is used posteriorly and anteriorly on most chairs. Posterior or rearward tilt allows users to adjust their seat orientation angle while maintaining the seat-to-back and seat-to-leg rest angles. **Knee pivot tilt** operates closer to the client's knee, as opposed to under their center of gravity. This type of system typically allows for

15-20 degrees of tilt while maintaining the front seat to floor height, allowing the user to maintain contact of their feet with the ground for stability or propulsion with the lower extremities, as well as hemi-propulsion. This type of tilt is only available on manual wheelchairs.

Tilt or Tilt-in-Space will indicate posterior use and will be used interchangeably in this Position to accommodate the variations in language, approach, and products reflected in the research. “Anterior tilt” will indicate anterior use.

Additional tilt systems include lateral tilt. Research and applications of lateral tilt systems, which operate in the coronal plane, are not extensively studied but should be considered for medically complex individuals who cannot be accommodated by existing manual or power seat functions operating in the sagittal plane.

Recline: allows users to increase (open) or decrease (close) their seat-to-back angle while maintaining a constant seat angle with respect to the ground, moving only the backrest.

Elevating leg rests (ELR): manual or powered individual leg rests are mounted off the seat rail and allow users to flex or extend the knee relative to the seat. Additionally, ELRs with power articulation can provide adjustability by independently shortening or lengthening the leg rests for individuals with length discrepancies and/or joint limitations.

Center Mount Elevating-Articulating Foot Platform (AFP): The center mounted elevating-articulating foot platform allows individuals to maintain midline positioning of the lower extremities on a singular foot platform, or angle adjustable footplates while the knees flex and extend from a seated position. The articulation of the platform allows for the full extension of the knee without restricting joint mobility during extension. Customization and programming

of the AFP can allow for controlled extension, extended footplate-to-floor movement, and allow for combined or independent leg positioning to accommodate joint limitations and/or length discrepancies. The seat function that allows footplate-to-floor contact is also referred to as power height adjustable footplates, or power footplate extension, and is evaluated as a client-specific component that can be added to the AFP.

Overview of the Current Literature

Overview of Seat Function Use

Wheelchair users overwhelmingly view their seat functions as a necessity for daily functions, performance, and comfort. The use of power seat functions is complex, context dependent, and often used to enable participation in an occupation or meaningful activity (Titus & Miller-Polgar, 2021; Titus & Miller-Polgar, 2018). Power wheelchair users with complex seating and rehabilitation needs, such as those with amyotrophic lateral sclerosis (ALS) regard tilt, recline, and power elevating leg rests as indispensable components of their power wheelchairs (Ward et al., 2010)., In a qualitative study on the use of power and manual tilt-in-space chairs in residential facilities, participants in the Shankar et al. (2015) study identified autonomy, comfort, and activity participation as important uses of tilt-in-space chairs.

This RESNA Position notes that while both manual and powered options for tilt, recline, and elevating leg rests can offer similar physiological and clinical benefits, the selection of seat functions should be based on the specific clinical needs of the individual. Power seat functions are often necessary to ensure consistent and effective use, particularly in cases where the user's condition or mobility limitations make manual adjustments impractical or insufficient. Conversely, manual seat functions should be given consideration when power is not advised.

Due to individual complexities and contexts, differences exist between outcomes-driven, evidence-based recommendations and personal patterns of use, such as those for effective pressure redistribution (Schofield, Porter-Armstrong & Stinson, 2013). The factors influencing whether individuals adhere to recommended frequencies and angles when using seat functions are diverse and depend on individual body structures and functions, preferences, needs, goals, and the task being performed.

A study by Titus (2013) found that users see seat functions as intertwined with their daily activities, making it challenging to separate specific interventions that are recommended to be done independently, like pressure relief protocols. Additionally, some individuals may face difficulties with breathing or head control when using recline and tilt. Other users from the Titus (2013) study expressed that extreme tilt angles of 45-60° can disrupt functional positioning, tasks, and social activities. As a result, clinicians should stress the application of seat function use, provide thorough training on individualized usage strategies, and ensure safety precautions are understood (Liu et al., 2013).

For power wheelchairs to be used safely and as directed by the LCMPs, a specific number of actuators (motors) must be installed for seat function operation. The exact number of actuators required may vary depending on the manufacturer and the specific functions of the wheelchair.

When three or more seat functions are prescribed, it is necessary to integrate electronic connectors, expandable electronics, and a wiring harness to facilitate drive control connectivity, programming, and the use of each function. When specialty interface controls are needed for one

or two power seat functions, electronic connectors, expandable electronics, and a wiring harness are also required.

These hardware components are necessary to facilitate each user's abilities and their specific need for standard or specialized input methods to the drive controls. Specialty controls enable advanced programming of power seat functions, allowing for independent, efficient management of drive controls and seat orientation - necessary for function, postural control, pressure relief, and overall disease management.

Titus and Polgar (2018) acknowledge that safe mobility and engagement in meaningful activities contributes significantly to overall health outcomes and well-being. The complex rehabilitation technologies discussed in this paper are essential for preventing injuries and minimizing the adverse effects of limited mobility. Ensuring access to these seat functions and an appropriate wheelchair enables individuals to improve function, and live safer, healthier, and more fulfilling lives.

Posture and Positioning

Dicianno et al., (2015) established that seat functions enable wheelchair users to access a variety of positions required for daily function and productivity. Wu et al., (2016) confirms this guidance, further recommending periodic movement through frequent adjustments or “dynamic” movement in the seated position to improve posture, productivity, and decrease pain. To determine the medical necessity and appropriateness of each seat function, postural and positioning assessments are required. This process begins with a clinical evaluation on a firm, flat surface, such as a mat table, and thorough assessments of the nervous, sensory, and

musculoskeletal systems, including but not limited to balance, reflex integration, comfort, pressure, spasticity, and function.

In Wu et al., (2016) the term “dynamic repositioning” refers to the wheelchair user’s ability to adjust their posture and position using tilt, recline, and elevating leg rests. Unlike able-bodied individuals who can regularly shift their posture without external assistance, wheelchair users rely on seat functions to compensate for physical limitations that result from congenital, acquired, or degenerative illness and injury. Wu et al. (2016) further support that dynamic repositioning from the wheelchair allows users (and caregivers) to adjust the seated position for better task performance, pressure reduction, improved comfort, and overall well-being.

Manual and power seat functions may help to accommodate non-reducible postural impairments and joint contractures and reduce the risk of further development (Dicianno et al., 2015, Bowers et al., 2020). Matching seat function use with non-reducible joints and other end-range limitations of the joint or muscle is crucial to identify and assess during the evaluation, with focus on prevention and management of contractures and orthopedic deviations. Bowers et al., (2020) advise that tilt-in-space may be recommended to not only address postural issues but to also prevent further deterioration of spinal postures. Care must also be used when prescribing these seat functions to ensure that movement is not allowed at a joint that cannot tolerate movement due to a contracture, to prevent injury or poor posture in the seating system which could lead to further issues, such as skin breakdown. This RESNA Position supports the findings within Bowers et al., (2020), along with the consideration of tilt-in-space and custom molded seating for individuals with significant postural asymmetries and non-reducible orthopedic deviations.

Postural Alignment

The following section discusses how seat functions contribute to functional positioning, postural alignment, accommodation of non-reducible postural impairments (non-correctable joint and muscular contractures), and client specific benefits of repositioning and adjustment in a seated position.

Tilt-in-Space: Titus and Polgar (2018) cited that the use of tilt to maintain posture and provide support has a direct link to pressure management, further addressed in this paper under the section discussing Pressure Relief and Tissue Perfusion. In addition to promoting neutral orthopedic postural alignment, clinicians also report using tilt to accommodate limited trunk and head control for enabled environmental interaction (Titus & Polgar, 2018). Residents of long-term care facilities who use manual or power tilt-in-space chairs reported improved positioning, comfort, sitting tolerance, and greater sense of physical ease in their wheelchairs (Shankar, Mortenson & Wallace, 2015).

Titus & Polgar (2018) indicate that aligning the angle of tilt with the angle of the individual's body posture is useful for maintaining postural alignment when performing dependent transfers with patient lifts. Use of the tilt seat function for this purpose assists in achieving optimal placement on the cushion and backrest and is further aided by the assistance of gravity. Additionally, use of tilt for mechanically dependent transfers reduces manual repositioning of the user, protecting joint integrity and reducing risk of friction and shear.

Recline and elevating leg rests/Articulating Foot Platform: Before discussing the benefits of postural alignment related to use of recline and elevating leg rests, biomechanical influence on anatomical structures must be well understood. Understanding the mechanics of two-joint muscle

groups like the hamstrings and quadriceps is necessary for maintaining neutral postural alignment. This knowledge guides the determination of the optimal degree of recline and leg elevation range to achieve desired postural support and alignment without compromising positioning.

A study on hamstring stretching by Lee, Sim & Jin (2021) explains that the hamstrings are a two-joint muscle group. Three separate hamstring muscles connect the pelvis to the tibia in the lower leg. Each muscle originates from the ischial tuberosities (IT) and inserts into the lateral and medial heads of the tibia, thereby crossing the joints of the pelvis and the knee. The study further indicates that hamstring length and tension can be controlled by the available ranges of the pelvis-femur angle and the femur-tibia angle.

The lumbar curve is temporarily neutral for seated individuals with normal range of motion through hip flexion and pelvic extension; however, decreased range of motion leads to shortened hamstrings, contributing to sacral sitting, pelvic instability, asymmetrical rotations, and other destructive postures of the posterior chain. When hamstrings are tight or contracted, the pelvis is forcibly pulled into posterior pelvic tilt, causing greater exaggeration (flattening) of the natural lumbosacral curve and vertebrae. Knee extension for individuals with this presentation creates trunk and pelvic instability. Additionally, Lee, Sim & Jin (2021) noted that flexible hamstrings improve lumbar flexion and allow for better head, neck, and trunk postures.

Assessments of individuals in both supine and seated positions provide clinical insights into the available ranges of rotation, flexion, and extension for trunk, pelvic, hip and knee and ankle mobility.

Concurrent access to recline is essential when using elevating leg rests or an AFP to reduce the risk of posterior pelvic tilt (sacral sitting), particularly for individuals with shortened, spastic, or tight hamstrings and hip flexors. Use of elevating leg rests or AFP without concurrent recline worsens peak pressure forces under the IT's, coccyx, and sacrum, and can be problematic for postural control.

Individuals with hamstring length limitations should recline their backrest while elevating the leg rests to prevent posterior pelvic rotation and overstretched musculature (Wu et al., 2016). Using recline and leg rest functions provides access to user-specific angles and supports independent repositioning, allowing the use of footplates and armrests for weight shifting. This combination improves opportunities for postural management and self-care at wheelchair level while accounting for postural and musculoskeletal variations that otherwise limit functional, safe ambulation.

Transfer Biomechanics

Seat functions are frequently used to improve transfer biomechanics and overall safety of both the wheelchair user and the caregiver before, during, and after transfers. Dicianno et al. (2009, 2015) highlighted that the seated individual could use tilt and recline to stabilize their trunk and position themselves properly for a transfer. Dicianno et al. (2009) further stated that recline may be used in combination with elevating leg rests to improve the safety and biomechanics of lateral transfers (to beds, tilt tables, standers) for a person in the supine position, accommodating for the necessary trunk position while providing a stable base of support under the feet.

As stated, using the posterior tilt seat function is beneficial when an individual is being transferred into the wheelchair using an assistive device such as a patient lift (Titus & Polgar, 2018). This method of tilting the seat posteriorly (rearward) when performing a mechanical patient lift transfer to the wheelchair can facilitate improved positioning of an individual's hips and minimize forward sliding, which places a considerable source of friction and shear on gluteal tissues. Following a transfer, the user may then be able to adjust angles for tilt, recline, and leg rests to achieve preferred positioning, with or without assistance of a caregiver (Titus & Polgar, 2018).

Alternative seat functions are available for individuals who are able to transfer with modified independence, such as manual or power anterior tilt, power seat elevation, power leg rest extension, and power flip-up footplates. In a study by Rice et al., (2019) participants (n=10) demonstrated that anterior tilt facilitates weight shifting to the front edge of the seat, allowing firm foot placement on the floor for squat-pivot and standing transfers. Rice et al. (2019) outcomes revealed that anterior tilt significantly improved transfer quality when combined with personalized clinical guidance on the use of the seat functions.

Power leg rest extension allows for vertical travel of the AFP footplates or foot platform for level floor contact. With this function, a user may lower the footplates to be flush with the ground to support a user's weight for a squat pivot or stand pivot transfer, thereby eliminating the need to physically flip the footplates up and out of the way, or transfer around the footplates while they are down. Research is limited on this innovative seat function, however, clinical practice has demonstrated that the use of footplate-to-floor contact allows for improved independence and safety during transfers, particularly for users who do not have the physical

capability to move them. Power flip-up footplates are also offered as an ancillary seat function to address this performance area.

Functional and Dynamic Positioning

Functional positioning, defined as the alignment or position in space necessary for individuals to engage in tasks actively or passively, and is the foundational goal for the seating and wheeled mobility user. Insufficient equipment or lack thereof can worsen the degree of functional impairment, limiting capacity for independent mobility (Prewitt & Pucci, 2015).

Clinical consensus has established that a wide variety of seat function combinations throughout the day helps individuals improve function and general productivity (Dicianno et al., 2015). Perceptions of how an individual can use seat functions for dynamic repositioning is influenced by clinical guidance and relies on education and specific task-oriented training for meaningful goals and desired participation in an activity (Bowers et al., 2020).

Clinical consensus also supports the functional benefits of combined uses of tilt, recline, and elevating leg rests. Maximizing the angles of recline, tilt, and elevating leg rests allows individuals to access the supine position for nearly all self-care tasks and supports safer transfers to beds and other seating surfaces. Combined use of multiple seat functions provides opportunities to reduce strenuous transfers, and the risk of injury to the wheelchair user and caregiver during the transfer for all transfer methods.

Additionally, people with complex diagnoses and mobility related disabilities often require more frequent medical visits and exams; a wheelchair with multiple seat functions allows for greater access to medical and dental care, not only when used in and as a means of transit, but also as an alternative exam table. Finally, the physiological benefit of multi-functional

positioning extends to multiple body systems and demonstrates systemic benefits such as: vital organ capacity, circulation, respiration, edema management, pressure management and tissue reperfusion.

Tilt-in-Space: Participants in the study by Titus and Polgar (2018) highlighted the use of tilt to enhance posture and positioning among wheelchair users. The researchers reported that tilt allowed for optimizing function and posture while maintaining position, conserving energy, improving sitting tolerance, and reducing the need to return to bed. The participants reported using tilt to sit up straighter, sustain upright posture, and achieve functional positions such as washing hair in the sink, as noted in Titus & Polgar (2018) and Harrand and Bannigan (2016). Additionally, tilt is used to prepare for caregiver-assisted transfers, and Shankar, Mortenson & Wallace (2015) observed residents of long-term care facilities were more involved in the direction of their care related to positioning.

Participants also described how tilt-in-space allowed sufficient rearward positioning assistance during transfers and safer positioning against gravity for downhill ramp navigation (Titus & Polgar, 2018). The use of tilt is further supported by Wu et al., (2016) in which participants noted that tilt helped when completing personal care activities, while driving the chair, and during peer engagement.

Titus & Polgar (2018) study participants also noted the use of tilt reduced position loss and the discomfort caused from sliding forward compared to non-tilted seated positions. This RESNA Position interprets “sliding forward” to mean slouching into posterior tilt, or sacral sitting, a harmful position that results in postural instability, greater shear forces on the skin, and functional limitations. Unrelated to pressure management, Titus & Polgar (2018) reported that

people will use power tilt to reposition themselves when they feel discomfort or when repositioning is required as the day progresses to reduce sliding into posterior pelvic tilt, which will result in, or can result from discomfort and fatigue.

Additional clinician-reported instances of power tilt usage align with user accounts, frequently involving efforts to minimize sliding and slouching in the seating system as the day goes on (Titus & Polgar, 2018). Use of power tilt to make small changes in positioning throughout the day was explored through a study of 6 residents and 10 staff members of a residential care facility whereby researchers determined that power tilt in space provided residents with more control over their positioning compared to manual tilt in space. In addition, with this small group of participants and staff, it was determined that the use of power tilt in space wheelchairs provided an opportunity for individuals to remain in their chairs for longer periods of time when comparing manual tilt in space because of being able to vary their position with increased independence (Shankar, Mortenson & Wallace, 2015).

Manual wheelchairs with knee-pivot tilt mechanisms offer several benefits for users, particularly those who rely on foot propulsion and those with conditions such as hemiparesis or hemiplegia. These wheelchairs help maintain an upright trunk posture and promote pelvic stability, which is foundational for effective and safe mobility (Prewitt & Pucci, 2015).

The knee-pivot tilt mechanism allows for functional positioning that supports users in avoiding posterior pelvic tilt, reducing the risk of shearing, and sliding forward in the seat. Improvements in postural stability minimizes discomfort and potential injury during movement. Moreover, the design preserves the front seat-to-floor height necessary for effective heel strikes and facilitating propulsion of the wheelchair using foot movements.

Research by Sonenblum et al. (2011) provides a rationale for using smaller, frequent tilt changes in clinical practice, aligning well with the capabilities of knee-pivot tilt chairs and their more limited tilt range. The mechanical adjustability of a knee-pivot tilt provides versatility in positioning, stability needs, and comfort while supporting a range of ADL's and functional tasks. It is especially important for personalized care, enabling users to adapt their seating position to their specific needs and preferences throughout the day.

Anterior tilt: Rice et al. (2019) conducted a pilot study on the use of anterior tilt that provided insights to use and benefit for participants with Cerebral Palsy, Multiple Sclerosis, Spinal Muscle Atrophy, and Muscular Dystrophy. The use of anterior tilt in this study (n=10) proved instrumental in promoting optimal spinal alignment by facilitating anterior (forward) pelvic tilt in individuals with greater tendency to collapse through the trunk secondary to fatigue and atrophy. By offering opportunities to tilt the pelvis forward, anterior tilt mitigated the risk of posterior pelvic tilt and leaning to one side to seek support of an armrest, both positions that can lead to discomfort and musculoskeletal imbalance over time. As one participant remarked, "I noticed that anterior tilt helped me sit up straighter and relieved the pressure on my lower back, making me feel more comfortable throughout the day." Additionally, Rice et al. (2019) noticed that head and neck alignment improve with use of anterior tilt, which reduces strain on muscles required for respiration and speech production.

Functionally, anterior tilt was beneficial for vertical, horizontal, and overhead reaching, allowing participants greater independence with grocery shopping, accessing elevators, and medication management. As expressed by one participant, "Before, I struggled to reach items on high shelves, but now with anterior tilt, it's much easier to grab what I need." Additionally,

participants reported improved perception and ability to participate in meal preparation tasks, highlighting the practical impact of anterior tilt on daily living activities (Rice et al., 2019).

Elevating leg rests: Based on participant self-report in a study by Bowers et al. (2020), individuals use elevating leg rests to assist with adapting position for maneuvering in specific environments. For example, leg rests need to be elevated for ascending or descending ramps to create footplate clearance, and for use when the chair is driven over unlevel terrain (Bowers et al., 2020), or larger thresholds. The study also found that powered lower extremity positioning increases independence and performance in dressing, personal care, and bowel/bladder programs when used with recline. Additionally, stable foot plates provide a solid base, making it easier to reach for items.

Recline: Adjusting the seat-to-back angle on wheelchairs helps individuals, especially those with poor or no trunk control, find a stable position to complete tasks. Bowers et al., (2020) cited several benefits of recline for functional positioning, including evidence that user-specific degrees and preferences for recline provided greater comfort, and that customizing the seat-to-back angle was necessary during mealtimes, while socializing, and while completing self-care activities such as bowel and bladder programs, lower body dressing, and wound care.

Tilt and Recline: Wheelchair users often face environmental limitations when fitting under tables in the community. Recline can be used to lean away from a table or desk without moving the armrests. However, most tilt mechanisms also move the armrests, making tilt impractical under a table unless the armrests are removed or flipped back. In such cases, the ability to make small adjustments to the recline angle can be useful for functional positioning (Dicianno et al., 2015). Thus, for power wheelchairs and manual wheelchairs equipped with

rotational tilt, the use of recline is a functional alternative for accessing tables, desks, and small spaces. However, a manual wheelchair with a knee-pivot tilt mechanism can provide up to -7° of anterior tilt and up to 27° of posterior tilt, with the seat rail parallel to the ground at 0°, and without changing the armrest position, offering greater environmental access and functional positioning (Prewitt & Pucci, 2015).

Pregnancy in individuals with Spinal Muscular Atrophy, Multiple Sclerosis, Spinal Cord Injury, Cerebral Palsy, and other chronic disabilities is not well studied. Still, the authors of this RESNA Position have observed that tilt, recline, and elevating leg rests can be used for functional repositioning for individuals who are pregnant. Opening the seat-to-back angle and using tilt creates expanded organ capacity during pregnancy, facilitates exam positioning, and further provides positioning assistance for nursing mothers and their newborns.

Body Functions

Dicianno et al., (2009, 2015) highlight the efficacy of seat functions in enhancing postural alignment and aiding individuals in managing orthostatic hypotension, exercise intolerance, and visual orientation. Further, by adjusting body positions using seat functions, individuals can reduce pathological movements such as fluctuating tone, spasticity, and non-integrated reflex patterns. This not only improves postural stability but has been clinically observed to improve body functions such as speech, alertness, arousal, respiration, eating, and the ability to carry out bowel and bladder programs.

Orthostatic hypotension refers to a drop in blood pressure upon sitting up and standing, which can lead to dizziness or fainting. Titus & Polgar (2021) prescribe the use of tilt for blood pressure management; as one participant stated, “I’ve got really low blood pressure, so I am

always tilting back or tilting up [to manage the fluctuations].” Exercise intolerance refers to the inability to perform physical activity at a normal level, often due to cardiovascular or respiratory issues; seat function use provides opportunities for energy conservation and recovery. Visual orientation refers to the ability to perceive and interpret visual cues about one's surroundings; use of tilt and recline allow for greater head control, reduced cervical hyperflexion, and improved field of vision for individuals with poor trunk control and orthopedic deviations of the spine.

Dicianno et al., (2009, 2015) updates also acknowledged using elevating leg rests combined with tilt to elevate the legs approximately 30 centimeters above the heart for effective edema management. Fujita et al. (2010) showed similar benefits in a control group without disabilities, using elevating leg rests and tilting more than 30° in combination with full recline to significantly improve lower limb hemodynamics. Wu et al. (2017) supports the use of both seat functions as an effective method for edema management.

Wecht and Harel (2013) demonstrated that up to 90% of people with spinal cord injury (SCI) experience some level of cardiovascular autonomic dysfunction and having the opportunity to use power seat functions to change position allows these individuals and their caregivers opportunities for immediate symptom management. Autonomic Dysreflexia is common in individuals with SCI above the T6 level, particularly for acute injuries, and is a life-threatening condition if left untreated.

Benjapornlert et al. (2020) support the use of a reclined position in individuals with dysphagia. Their findings suggest that reclining may aid in reducing the risks of penetration and aspiration, as well as diminishing residual amounts of organic material in the pharyngeal region. Yoshikawa et. al (2019) demonstrated that poor posture including slouching (increased forward

flexion) decreased the amount of force the tongue could produce when compared to sitting upright. This confirms the need for proper upright sitting posture to maintain adequate oral function for eating and swallowing. The use of tilt and recline can assist with maintaining optimal head, neck, and trunk alignment against gravity to achieve an upright position to facilitate a safe swallow.

New research confirms that the use of seat functions can serve as a complementary clinical intervention and a component of 24-hour positioning protocols. These protocols have demonstrated efficacy in improving oxygen levels, decreasing tone, and enhancing function in children with cerebral palsy when supportive sitting and supportive lying are used as concurrent clinical interventions (Rauf et al., 2021).

Further, Osborne et al. (2023) emphasize that a comprehensive 24-hour approach to postural care is essential for individuals who lack the ability to independently change their body position. The Postural Care Management (PCM) approach focuses on the strategic management of an individual's body position throughout the day, whether sitting, standing, or lying down (Kittleson et al., 2024). The goal of PCM is to provide comprehensive postural support for individuals who require assistance with repositioning, ensuring they are properly aligned for all activities. This approach also emphasizes the importance of utilizing appropriate technologies to prevent and manage co-morbidities and secondary conditions associated with limited mobility and prolonged periods of being bedridden. Consistent attention to posture, even during periods of rest or sleep, plays a vital role in maintaining musculoskeletal integrity and preventing the progression of physical disabilities (Kittleson et al., 2024).

Pressure Relief and Tissue Perfusion

Research cited within Dicianno et al. (2009, 2015) pertaining to pressure values over specific areas of concern, including the ischial tuberosities (IT) and sacrum remain relevant in practice as guides for individual treatment planning of active pressure injuries and preventative care. The following chronological review of the existing evidence underscores the significance of providing both manual and power seat functions to enable diverse wheelchair seating orientations for prevention and management of pressure injuries. Recent research builds on existing evidence related to pressure management and explores the integration of smart technologies in wheelchairs to assist individuals with memory, attention, and communication deficits. These advancements include cognitive prostheses, which are digital tools designed to aid cognitive functions such as memory and attention, and real-time biomechanical feedback systems that optimize seat function and analyze interface pressure values.

a) Summary of Existing Evidence

Makhsous et al. (2007) found that standard wheelchair pushups are inadequate for tissue perfusion, as each pushup would need to be maintained for 2 minutes to effectively reduce oxygen tension in the tissues, regardless of frequency or repetition. For some wheelchair users, performing pushups as frequently as once per minute could lead to repetitive strain injuries (affecting the arms, head, neck, and cardiovascular system). Consequently, Makhsous et al. (2007) concluded that wheelchair pushups are ineffective for achieving sufficient tissue reperfusion and reducing interface pressure on the ischia.

Chen et al. (2010) demonstrated that increasing tilt angles from 0° to 35° was associated with decreased pressure on the sitting surface. This finding indicates an inverse relationship between

tilt angles and buttock pressure, suggesting that greater degrees of tilt and recline are linked to reduced pressure profiles.

Jan et al. (2010) explored the effect of wheelchair tilt-in-space and recline angles on skin perfusion over the ischial tuberosities in individuals with spinal cord injury (SCI). Their study employed Laser Doppler Flowmetry and interface pressure measurement to assess blood flow and pressure changes at different tilt angles. They found that tilt angles greater than 30° were necessary to achieve significant pressure reduction, while blood flow increased with tilt but did not significantly increase from 15° to 30°. The study highlighted that maximal tilt (45°–60°) was most effective in enhancing blood flow and reducing pressure. The Jan et al. findings recognized the importance of using substantial tilt angles for effective pressure relief and improved skin perfusion.

Sonenblum and Sprigle (2011) investigated the biomechanical responses to seated tilt in individuals with SCI, focusing on blood flow and localized tissue loading. Their study, using Laser Doppler Flowmetry and interface pressure measurements, found that tilt angles of 30° and above resulted in noticeable pressure reduction. However, significant increases in blood flow were observed only at tilt angles greater than 30°, with some participants experiencing notable benefits at 45° to 60°. They discovered that smaller tilts (15°) did not substantially increase blood flow or decrease pressure, suggesting that while smaller tilts provide some benefit, more significant tilts are needed for optimal pressure relief.

The research of Jan et al., and Sonenblum & Sprigle provide valuable insights into how different tilt angles affect biomechanical responses such as blood flow and pressure changes. This variability in use of and need for tilt suggests that a one-size-fits-all approach may not be

effective, and interventions should be personalized to meet individual needs. Modern clinical practice is aligned with these foundational findings, and maintains focus on individualized care to improve comfort, functionality, and prevention of pressure injuries (Jan et al., 2010; Sonenblum & Sprigle, 2011).

Jan et al. (2010) and Sonenblum and Sprigle (2011) challenge the earlier belief that large tilt angles of 45° or more are required for effective pressure relief. Their research indicates that even smaller tilt angles, such as 15°, can be beneficial, especially for enhancing blood flow. These findings remain relevant and continue to guide best practices in seating and mobility.

The research findings and details from Dicianno et al. (2009, 2015) regarding the effects of tilt, tilt and recline, and recline on tissue perfusion in the ischial tuberosities, sacrum, and coccygeal areas, as compared to upright sitting (0° of tilt), are summarized in Table 1.

Table 1.

Research Study	Clinical Findings
Jan et al. (2011)	Tilt of 35° combined with recline of 100°, or tilt greater than 25° with recline of 120°, is clinically significant for tissue reperfusion around the IT in users with SCI.
Sonenblum & Sprigle (2010, 2011)	Tilt of 30° or more resulted in reductions in mean and peak pressure at the IT. Tilt of 15° showed no effect on IT pressure.
Giesbrecht, Ethans & Staley (2011)	Tilt of less than 20° was ineffective for reducing peak pressure at the IT or sacrum. Tilt of 30° with recline at 100° significantly reduced peak IT pressure by 20%, and sacral pressure by 10%. Tilt of 40° with recline at 100° showed a 40% decrease in peak pressure at both IT and sacrum.
Park & Jang (2011)	Recline of 90°-130° progressively reduced peak pressure at the IT, but did not change pressure at the sacral area.

Jan & Crane (2013)	Tilt of 35° and recline of 120° did not affect sacral skin perfusion, attributed to pressure redistribution across lumbar and thoracic areas.
Jan et al. (2013)	Muscle perfusion at the ITs was greater at tilt of at least 25° with recline of 120°, or at least 35° of tilt with recline of 100°. Skin perfusion was greater at tilt angles of at least 15° with recline of 120°, or at least 35° of tilt with recline of 100°.

In summary, the findings from Dicianno et al. (2009, 2015) indicate that specific combinations of tilt and recline angles are essential for effective pressure redistribution. The research suggests that relying solely on posterior tilt with angles less than 15° is insufficient for significant pressure reduction. However, combining tilt with recline at angles of 25° and 65°, respectively, demonstrates improved pressure distribution and reduced shear. This combination effectively spreads pressure over a larger surface area, mitigating shear risk. Complementing this, Jan et al. (2010) observed that the most substantial pressure reduction occurred with tilt angles between 25° and 45°, when combined with recline angles ranging from 110° to 150°. These findings demonstrate the importance of integrating both tilt and recline to achieve optimal pressure management and skin integrity.

b) New Evidence

Pressure injuries represent a significant concern for manual and power wheelchair users, particularly due to the loss of mobility and loss of sensation, key risk factors for their development (Campeau-Vallerand and Michaud, 2017). Pressure relief and tissue perfusion are critical aspects of care for individuals who use wheelchairs, particularly those who are unable to physically shift their weight to offload tissues. While this is especially pertinent for individuals

with spinal cord injuries (SCI), it is also crucial for anyone using a wheelchair who may be at risk of developing pressure injuries or who already has them. Recent advancements in technology and research have focused on developing innovative solutions to address these concerns and optimize tissue health in wheelchair users.

This update to RESNA's Position considers new evidence from studies exploring various pressure relief techniques. These include the use of tilt-in-space functionality, dynamic positioning, and advanced monitoring systems. This Position stresses the importance of individualized evaluations and pressure mapping for high-risk clients by skilled LCMP's and individual positioning considerations for promoting effective pressure relief and optimizing tissue perfusion outcomes for wheelchair users across different populations.

Campeau-Vallerand and Michaud (2017) developed a web-based monitoring system for power tilt in space wheelchairs based on the frequency, angle, and duration of use of tilt. Tilt ranges of 11° to 55° have been shown to decrease pressure on the seating surface, with optimal benefits achieved per the recommended tilting every 30 minutes for at least 1-2 minutes. The system utilized pressure mapping and position sensing technologies to detect pressure injury risk factors of "loss of mobility" and "lack of sensitivity" and provided personalized reminder settings among the study participants (n=5) who have Cerebral Palsy (3) or Quadriplegia (2). The participants in this study recognized the need for personalized reminder settings based on different functional contexts, such as work, school, and leisure activities, and all users mentioned that the tilt reminder encouraged them to tilt more often.

Campeau-Vallerand and Michaud (2017) emphasized user involvement in the development process and addressed person-centered preferences that allow users to set personalized goals for

tilt, in addition to the recommended goals. The data indicated a user preference for individual considerations of tilt parameters (frequency, angle, duration) to identify needs for goal setting and effective use. Power wheelchair users provided feedback on feasibility, usability, and usefulness, and most users (n=3) mentioned that the feedback available from the interface was a source of motivation to help them achieve their pressure management goals. Additionally, the option to set client centered goals helps the clinician receive feedback to determine whether their recommendations are truly adapted to the variability of the individuals' daily occupations. This technology and web-based monitoring system accurately monitored tilt, recline and pressure parameters, providing real-time feedback to improve user comfort and reduce the risk of pressure injuries, though tilt was the focus of this study. The researchers posited that this intervention prototype could promote optimal use of the tilt seat function, and improve clinical post-procurement follow up, which was confirmed by the findings of this study.

Chen et al. (2014) reported the effect of tilt and recline on ischial and coccygeal interface pressures in people with SCI, finding that recline and tilt positions reduced interface pressure in both areas. In this study (n=13), power wheelchair users were pressure mapped in six combinations of wheelchair tilt (15°, 25° and 35°) and recline (10° and 30°, corresponding to traditional recline angles of 100° and 120°, respectively). Combinations were tested in 5 minutes of upright sitting, 5 minutes of tilt and recline (tested in random order) and 5 minutes of maximum pressure relief recovery to accurately collect peak pressure indices at the ischial and coccygeal sites. The results indicated reductions in pressure at the ischial tuberosities when using combinations of tilt and recline and showed that 15° of tilt or less did not produce significant effects, regardless of the recline angle.

Chen et al. (2014) did observe that when the wheelchair seat to back angle is reclined (opened) by 10°, there is a notable decrease in pressure under the ITs as the tilt angle increases from 15° to 35°, suggesting tilt may help alleviate pressure on these areas and thereby reduce the risk of pressure injuries. However, use of 10° of recline and incremental ranges of 15°- 25° of tilt or 25°-35° produced no significant differences, indicating the benefits of these respective ranges are similar when combined with 10° of recline.

When evaluating pressure over the coccygeal area, 10° of recline, paired with any angle of tilt (15°, 25°, 35°) showed no reduction in interface pressure on the coccyx. However, with 30° of recline, a significant decrease in coccygeal pressure was noted with each tilt angle. Finally, Chen et al. (2014) tested 15° and 25° angles of tilt with recline angles of 10° and 30° on coccygeal pressure and identified no significant offloading difference, but with 35°of tilt and recline angles of 10° and 30°, they noted a significant decrease in coccygeal pressure. The research findings also highlight an area of caution, noting that smaller angles of tilt and recline distribute greater pressure to the coccygeal area, but larger combinations of tilt and recline redistribute pressure to lumbar and thoracic areas. Chen et al. (2017) acknowledges the importance of considering the effects of person-centered positioning on pressure and tissue perfusion, and indicates a positive correlation between user safety, comfort, and pressure injury prevention when tilt and recline are used dynamically and concurrently.

De Souza and Frank (2020) conducted a cross-sectional study involving 57 individuals with spinal cord injury (SCI) who relied on power wheelchairs for mobility. Their study highlights that pressure injuries are a prevalent complication among SCI patients, though the researchers discovered that individuals using wheelchairs equipped with tilt-in-space functionality had a

notably lower risk of developing pressure injuries compared to those using standard power wheelchairs without such seat functions.

De Souza and Frank (2020) indicated that the primary clinical advantages of tilt-in-space systems are pressure reduction, improved pain relief, and comfort. Their study also identified several comorbidities, including low back pain, failed spinal surgery, scoliosis, problematic pain, heart disease, and pressure injuries, all of which increase the need for regular weight shifting and positional adjustments among SCI patients. Additionally, the study noted that inadequate pressure relief and poor sitting posture, such as postural asymmetries (e.g., kyphosis, scoliosis, obliquities) and obesity, exacerbate peak pressure on bony prominences and elevate the risk of pressure injury development. De Souza and Frank (2020) also confirmed the efficacy of using pressure-relieving cushions alongside tilt-in-space functionality for individuals who are unable to relieve pressure through manual push-ups or independent weight shifts.

Pain, Comfort, Fatigue, Sitting Tolerance, and Participation

Pain, comfort, and fatigue are factors that significantly influence the utilization of seat functions and the overall sitting tolerance of wheelchair users. This RESNA Position defines sitting tolerance as the length of time a wheelchair user can remain in their wheelchair without experiencing pain, significant pressure problems, or postural changes caused by fatigue.

In the context of power tilt, recline, and elevating leg rests, sitting tolerance is often associated with the maintenance of skin integrity, wound care, and pressure management, as well as ability to complete mobility related ADLs. Recent findings suggest that the effective management of pain, comfort, and fatigue through the use of seat functions can enhance sitting

tolerance, thereby improving quality of life (QOL) and participation in daily activities (Dolan et al., 2019).

A summary of evidence within Dicianno et al. (2015) demonstrates that most wheelchair users utilize seat functions primarily for comfort. They frequently use tilt angles from 5°-15° and recline angles from 95°-110° to enhance sitting stability and support functional activities, which can improve sitting tolerance. The existing evidence also determined that users experience less discomfort related to vibration when seated in a reclined position compared to an upright position.

Pain and fatigue are reported to limit activity in wheelchair users with SCI, those with paraplegia being more frequently affected than those with tetraplegia (De Souza and Frank, 2020). Dicianno et al., (2015) states that "pain may result from prolonged sitting, pressure, and inability to change position." Most wheelchair users relate their pain to their underlying medical conditions and, in some cases, to improperly configured wheelchairs. However, in contrast, 25% of users report using their wheelchair to treat the pain by allowing position changes (Frank et al., 2012).

Wu et al. (2017) investigated how varying the frequency of power seat functions, particularly tilt and recline, impacts wheelchair comfort. The study sought to determine the specific changes in tilt, recline, and leg rest angles that lead to significant reductions in discomfort intensity. Using the Tool for Assessing Wheelchair disComfort (TAWC), which measures discomfort across seven body areas from 0 (no discomfort) to 10 (severe discomfort), the researchers found that frequent adjustments in tilt and recline notably improved comfort. This effect was further enhanced when combined with elevated leg rests. Reclining the backrest helps

prevent posterior pelvic rotation caused by tight hamstrings, which can lead to a slouched posture. Access to this postural adjustment is thought to ease lower back muscle tension.

Wu et al. (2017) found that frequent use of power seat functions such as tilt, recline, and elevating leg rests significantly reduces discomfort intensity for wheelchair users. By demonstrating that each function independently contributes to reduced discomfort, the study underscores the potential for tailored interventions to meet individual needs and enhance user satisfaction (Wu et al., 2017). Prolonged sitting without such adjustments can lead to postural issues like flattening of the lumbar curve and muscle deconditioning, which contributes to fatigue even under minimal loads (Jung et al., 2021).

Similarly, Harrand and Bannigan (2016) observed that combining various power seat functions, including tilt and recline, can offer additional therapeutic benefits. Their research indicates that these combinations can improve seating comfort and help maintain skin integrity, an important aspect of care for individuals who are at high risk of pressure injuries due to extended periods in their wheelchairs. This evidence supports the integration of multiple seat functions into clinical practice, as it provides a comprehensive approach to managing pain, preventing pressure sores, and promoting overall well-being (Harrand & Bannigan, 2016).

In our opinion, the study results suggest that fatigue in this context refers to postural fatigue, which arises when a wheelchair user is unable to make dynamic position changes without assistance. This limitation justifies the clinical need for manual or power tilt, recline, and leg rest functions to mitigate discomfort. Additionally, a negative change in postural alignment can lead to pain, decreased comfort, poor sitting tolerance, and reduced participation in daily activities, further underscoring the necessity of these power seat functions. However, limited

research exists on the specific effects of leg rest usage in conjunction with tilt and recline on comfort and pain management (Wu et al., 2017).

The use of seating functions to manage pain, comfort, and fatigue can significantly increase sitting tolerance and participation in daily activities. In a study by Shankar et al. (2015), the experiences of long-term care facility residents using manual versus power tilt-in-space wheelchairs were examined, particularly focusing on individuals with varying abilities. Participants in the study were intentionally selected for their diversity in cognitive ability, cultural background, ability to propel their wheelchairs independently, and use of tilt. The residents included those diagnosed with dementia, stroke, diabetes, and spinal cord injury (SCI).

Power tilt-in-space users reported using their wheelchairs for longer periods due to perceived comfort, which contributed to improved sitting tolerance and increased mobilization for participation (Shankar et al., 2015). The analysis revealed a central theme of 'taking control,' with two sub-themes: 'promoting comfort' and 'mobilizing to participate.' The findings suggest that wheelchair users with power tilt may experience increased control, enhanced comfort, and greater freedom and independence in mobility.

Conversely, the effectiveness of manual tilt-in-space wheelchairs can depend on the user’s ability to self-advocate for position changes, and the presence and responsiveness of staff to assist with position changes. This reliance can affect users' mobility, independence, and their ability to access their environment. Thus, the functionality of tilt-in-space systems can significantly impact occupational engagement, emphasizing the need to consider environmental factors and support availability when choosing the appropriate manual or power tilt mechanism.

Knee-pivot tilt mechanisms in manual wheelchairs offer benefits for users needing both postural support and mobility. These systems typically provide a tilt range of 15-20°, which facilitates micro shifts and maintains postural stability while allowing for activities like self-propulsion and daily tasks. This function is especially valuable for individuals with hemiparesis or those needing mobility assistance to participate and engage with their environment. Research shows that knee-pivot tilts support optimal access to tables and sinks by preserving the front seat height, increasing access and participation in daily activities (Prewitt & Pucci, 2015). Moreover, this tilt mechanism improves trunk balance and stability, promoting independence and reducing the risk of pressure injuries and discomfort from prolonged sitting (Prewitt & Pucci, 2015).

Recent research has established a link between increased power wheelchair acceptance and higher activity levels, particularly with the use of seat functions. Stenberg et al. (2016) found that participants reported higher device acceptance when their power wheelchair met needs beyond simple ambulation, such as providing standing and tilting functions for reaching or pain relief. The study highlighted how power wheelchairs opened up new possibilities for daily activities and social engagement, including work, shopping, housework, leisure activities, and spending time with friends.

De Souza and Frank (2020) further emphasized that 'power wheelchairs are not only important for enhancing personal independence and participation but are now also considered ‘significant therapeutic tools.' Their study concluded that 'the provision of a power wheelchair with appropriate seating, such as tilt-in-space, can optimize the therapeutic role of power wheelchairs in managing severe mobility disabilities, while also enhancing mobility, independence, and participation.' Moreover, tilt is recognized as an essential therapeutic strategy

for individuals who spend extended periods in their chairs and have limited ability to change positions (Sonenblum & Sprigle, 2011).

Features such as specialized seating (SS) or adaptive seating, designed to promote optimal posture and enhance comfort, along with tilt-in-space functionality for pain control, pressure reduction, and fatigue management, are transforming the lives of power wheelchair users, some of whom may spend up to sixteen hours a day in their chairs (Frank et al., 2012). Specialized seating, also referred to as adaptive seating, is defined by the British Society of Rehabilitation Medicine (as cited in De Souza & Frank, 2020) as 'seating needed by people who require a wheelchair but, due to instability or deformity, need additional support to function.

Wu et al. (2017) emphasize that wheelchair users should adopt a dynamic sitting posture—periodically changing their position using seat functions—to achieve better wheelchair comfort, rather than maintaining a static posture for extended periods. The ability to independently manage these seat functions, with reduced reliance on caregivers, significantly influences sitting tolerance and promotes greater participation in activities outside of bed (Dolan et al., 2019; Shankar et al., 2015). In addition to independent repositioning via power mobility, some manual tilt in space chairs can accommodate the addition of a power tilt mechanism that can be added to the chair and operated by the wheelchair user or caregiver via a switch.

Pain, often subjective but significant, greatly influences wheelchair usage and the need for advanced seating functions. Research demonstrates that power tilt and recline functions can significantly improve comfort, reduce discomfort, and support active participation in daily activities. This evidence supports the necessity of considering both pain management and comfort when evaluating wheelchair features for optimal user outcomes.

In summary, the evidence and expert opinions indicate that seat functions like tilt, recline, and elevating leg rests are significant factors that influence wheelchair users' comfort, pain management, reduction of fatigue, and improved posture. Consideration of these factors, their influence on sitting tolerance, and the ability to use (or direct the use of) the wheelchair effectively is linked to greater participation in daily activities and a better quality of life. Therefore, clinicians should thoughtfully integrate these seat functions—whether manual or powered—into therapeutic strategies to maximize patient benefits and outcomes.

Quality of Life and Participation in Activities of Daily Living (ADLs)

Power seat functions allow wheelchair users to change positions and actively participate in meaningful activities, improving overall independence and quality of life by placing control within their control. Rice et al. (2019) explored the benefits of anterior tilt and reported it significantly improved vertical and horizontal reach with a resulting improvement in the ability to perform functional tasks and activities of daily living at home and work. For example, participants in this study demonstrated improved adequacy of performance and reduced assistance with meal preparation. This improvement in function could reduce or eliminate the need for caregiver assistance for this task. Further research is required to assess the overall impact of tilt and recline on occupational engagement and quality of lift (Harrand and Bannigan, 2016).

Bowers et al. (2020), highlighted the impact of an individual's social circle on participants' decisions regarding the use of wheelchair seat functions. The complex interplay between individual identity, social norms, and perceptions of others' behavior does influence wheelchair use and behaviors. Clinicians and researchers should consider these factors when designing interventions or support programs aimed at promoting the effective utilization of

wheelchair features and improving the quality of life for wheelchair users. By recognizing the diversity of individuals' identities and interests and addressing misconceptions about wheelchair use, interventions can be tailored to meet the unique needs and preferences of users. Fostering a sense of community and mutual support among wheelchair users may enhance social connectedness and empowerment, ultimately contributing to better outcomes and well-being.

Summary

RESNA asserts that the use of tilt, recline, elevating leg rests, and their ancillary capabilities are medically beneficial and essential for wheelchair users. As outlined in this paper, these functions play a critical role in enhancing transfer biomechanics, improving sitting tolerance and comfort, managing physiological processes and body functions, addressing postural and orthopedic deviations, redistributing and relieving pressure, increasing independence with activities of daily living, and ultimately optimizing the quality of life and participation in meaningful activities for individuals with mobility impairments. The recommendations in this paper are grounded in select peer-reviewed literature and reinforced by current clinical practice. Recognizing that research may not always be available on some innovations or issues related to assistive technologies, this document includes and summarizes other types of evidence, including credible clinical data and/or case examples, as well as expert opinion from cited sources.

While research is indispensable in advancing our understanding of Seating and Wheeled Mobility (SWM), the highly individualized nature of these practices presents challenges in fully capturing their complexities through traditional research methodologies. Each person’s needs, preferences, and circumstances vary significantly, meaning that standardized research findings may not entirely reflect the diversity of real-world applications. This limitation underscores the

importance of integrating research insights with clinical expertise and personalized care, ensuring that SWM practices are adapted to meet the specific requirements of each individual.

To support the effective implementation of these technologies, it is imperative that clinicians and suppliers are well-informed and equipped to deliver tailored solutions that address the unique needs of wheelchair users. Moreover, supportive policies are crucial in facilitating access to these essential functions, ensuring that individuals who rely on SWM can fully benefit from the advancements in this field. Advocacy for policies that recognize the value of individualized care, and the importance of these seat functions is necessary to improve outcomes for people with disabilities.

Limitations of the Current Literature

The current literature faces several significant limitations, including a lack of randomized controlled trials and other high-level scientific studies evaluating outcomes from the use of these technologies. This gap hinders the ability to draw definitive conclusions about the efficacy and long-term benefits of these interventions. Additionally, some referenced studies utilized ergonomic chairs and participants without disabilities, which were excluded from this review. This exclusion further limits the generalizability of findings to the populations most in need of these technologies.

The populations served by this equipment are diverse, encompassing both minors and adults, including individuals with cognitive and severe physical disabilities. Ethical and scientific challenges arise in conducting research with these groups, as participants in human subject research must be able to comprehend and cooperate with the anticipated tasks and interventions within the study, as well as give consent to participate. This requirement can restrict participation

to those who can fully commit to and engage in the research process, thereby narrowing the scope of studies.

Looking forward, RESNA's longstanding history of research, development, industry support, and innovation provides a strong foundation for addressing these limitations. As future generations of students and professionals engage with this field, there is a significant opportunity to expand the evidence base through rigorous, inclusive research methodologies. By leveraging RESNA's commitment to advancing assistive technology, the organization can continue to drive industry growth and improve outcomes for individuals with mobility-related disabilities. Through collaboration and innovation, the gaps in current literature can be addressed, leading to more comprehensive and effective solutions that meet the diverse needs of this population.

Case Example

Referral:

AH is a 35-year-old female who presented to inpatient rehabilitation after placement of an intrathecal baclofen pump to manage significant spasticity of unknown etiology. She has a history of right upper limb shoulder injury, complex regional pain syndrome, depression, bipolar disorder, as well as abnormal movement disorder. She does not have functional use of her right upper extremity and presents with contractures throughout, most significantly flexor contractions in her right wrist and digits. Her left upper extremity strength and range of motion are also impaired, as described below.

Prior to this hospitalization, AH was able to ambulate and did not need an assistive device for mobility. Upon admission, she was dependent for all ADLs and mobility, requiring use of an overhead or portable lift for transfers, and a manual tilt-in-space wheelchair. AH does

not have the ability to ambulate independently or self-propel a manual wheelchair due to absent use of her right upper extremity, as well as significant weakness and tone in her lower extremities. She is unable to perform any type of pressure-relieving weight shift independently. She was referred to the seating clinic for evaluation for the most appropriate complex rehab technology (CRT) to maximize her independence and decrease her burden of care. This evaluation was conducted by an advanced clinical occupational therapist who also has her ATP and SMS certifications from RESNA, as well as the ATP from the supplier company. AH's treating occupational therapist also provided input.

Assessment:

Body Structures and Functions

AH is 5'6" and weighs 120 pounds. Her past medical history is as above. Fatigue and arousal are a limiting factor, and she requires encouragement for participation and active use of her left upper extremity. Her LUE AROM is as follows:

Movement	Range of Motion
Shoulder Flexion	60 degrees
Shoulder Abduction	20 degrees
Shoulder External Rotation	10 degrees
Elbow Flexion	120 degrees

Forearm Supination/Pronation	20 degrees
Wrist Extension/Flexion	10 degrees

Her composite digit flexion/extension is variable as her tone fluctuates depending on her fatigue level. She can sustain gross grasp on self-care items post set up assist, however increased difficulty is noted with digit extension to release objects. As mentioned earlier, her left upper extremity has no functional use. She has contractures throughout including at the shoulder, elbow, wrists, and digits. Full assessment is limited by pain. She has absent grasp and release. Overall, her light touch sensation is impaired throughout both upper extremities.

A supine and seated mat assessment was performed for AH to determine any postural abnormalities and assist with ensuring an appropriate and safe seating system to enhance her function and prevent complications. In supine, she has a tendency toward posterior pelvic tilt and sacral sitting. Her lower extremity AROM is as follows:

Joint	**Range of Motion (degrees)**	**Notes**
Hip Flexion	110	Limited bilaterally
Knee Extension	40	With hips at 110°
Ankle Dorsiflexion	Right: 50, Left: 20	From neutral position
Hip External Rotation	Lacking	

Hip Abduction	Lacking

Seated, she also sits in a posterior tilt, which is non-reducible, and has a non-reducible right lower pelvic obliquity. Her thoracic spine demonstrates a non-reducible kyphosis, and her lumbar spine is flat. She presents with increased forward cervical flexion. Overall, she has poor endurance, dependent sitting balance for which she requires external support to remain upright.

Activities and Participation

Prior to her current hospitalization, AH was independent with all household and community mobility. She reports that she is a published author, and her leisure activities include writing and crocheting. She also spends time with family. Currently, due to pain and fatigue, she can only tolerate sitting in her tilt-in-space manual wheelchair for approximately 1 hour at a time, and only does this approximately 2 times a day, when she is with therapy. She reports that because she is unable to change position, including shifting her weight, she is unable to tolerate sitting in this chair for longer periods. She also reports she has difficulty finding someone that will assist her frequently enough, since she is dependent.

Environment

Prior to this hospitalization, AH was living at home with her father. Her parents are divorced but her mother is also involved in her care. The initial plan was for her to discharge to a community-based long-term care with a neurological focus, geared specifically towards wheelchair users, however, due to her past mental health medical history, which included a suicide attempt, she was denied transfer here. Neither parent can care for her at home, so the plan was for her to be transferred to a skilled nursing facility. Fortunately, this facility will be

accessible, and her insurance is such that they likely will approve a custom wheelchair in this type of discharge environment.

Team/Client Goals

1. Maintain postural alignment and decrease pressure to prevent postural deviations and pressure injuries, pain, and other complications.

2. Increase independence with functional mobility including navigating around her environment for participation in ADLs.

3. Increase her ability to independently change her position.

4. Increase independent access to assistive technology for socialization and leisure participation.

Equipment Recommendations and Selection:

To provide the most independence and functional mobility for this client, it was determined that a complex rehab power wheelchair with power seat functions would be most appropriate. Prior to trialing a power wheelchair, AH was utilizing a tilt-in-space manual wheelchair with manually height adjustable footplates. This allowed her caregivers to provide her with pressure redistribution and repositioning, however, she was unable to reposition herself and was not able to adjust this type of chair on her own. The tilt-in-space was a good starting point for seating trials however, including trailing different positioning backrests and pressure relieving/positioning cushions to ensure even pressure distribution, maintenance of midline position, and full use of her functional upper extremity.

After the seating was determined, the wheelbase was selected (mid vs front vs rear wheel drive set-ups). It was determined that a mid-wheel drive base with a small footprint would best serve this client regardless of discharge environment. Seat functions were addressed one by one, to determine the most appropriate combination of functions and to ensure she was safe using them. Power tilt was the initial recommendation, so that at minimum, AH would be able to independently tilt her chair back to shift her weight off the sitting surface of her buttocks. She was able to do this using a combination of the joystick and light touch switches that were provided and placed on her headrest so she could change modes.

She next requested to add the power AFP. She reported pain in her LEs and feet that was relieved by elevation. Since her hamstrings were tight, education was provided to her and her caregivers safe angles to use with the AFP to prevent her from sliding forward in the chair or sitting in a posterior pelvic tilt.

This led to further discussion about the use of power recline, which was trialed next. AH has a feeding tube and may also be evaluated in the future for a suprapubic catheter. The power recline would not only give AH more range to elevate her legs and would also decrease risks related to transfers, including fatigue, risk of falls or injury, and caregiver burden by allowing them to manage her feeding tube and catheter without transferring her.

Education was provided so that AH and her caregivers knew how to return the reclined backrest to an upright position so that she did not slide forward in the chair or increase pressure on her coccyx and sacrum by sitting in her chair with her backrest angle open a significant amount. When using combinations of the tilt, recline and elevating leg rests, returning to an upright position should be performed in the sequence of recline, elevating leg rests, and then tilt

toward a neutral upright position so that the pelvic position is maintained without friction or shear.

Funding and Procurement:

Due to AH's insurance benefit, the team was able to submit for this chair even though she was not discharging home. She and her family were educated on the process and throughout the order process they were informed of choices that may not be covered by insurance. Ultimately, the evaluating OTRL, ATP/SMS completed the documentation for justification of each part of the chair, gathered necessary paperwork, and obtained physician signatures. The supplier/ATP submitted all documents for pre-authorization, and notifies the clinician when approval is received, or if additional information is required from the clinician by the payer to clarify medical necessity.

Product Preparation:

The supplier/ATP and their team receive, inspect, and assemble the equipment and confirm delivery of all parts. The supplier/ATP then reviews the chair prior to delivery for accuracy prior to delivery.

Fitting, Training and Delivery:

With the client and the supplier/ATP, the evaluating therapist performed a review of wheelchair systems and seat functions, ensuring all components discussed and ordered fit the client. Programming parameters were set to achieve functional positioning and task performance goals appropriate for the client. This was done virtually via a meeting with the supplier on Microsoft Teams who was in person with the client at delivery.

Education Provided:

AH arrived at the clinic in a tilt-in-space loaner wheelchair accompanied by her mother. She and her mother were educated on safe and appropriate use of the device, including how to turn on/off, how to use the power seat functions, general maintenance, and who to contact should any technical or repair issues arise with the device, or if she experienced any problems sitting in or using the device. Manufacturer's manuals and owner's manuals were provided and reviewed.

Follow-up Maintenance and Repair:

Contact information for the seating clinic as well as the supplier were provided, and AH was encouraged to reach out with any concerns or questions. She was also instructed to call the supplier for operation/repair issues with the chair or her therapist if she experiences a seating/positioning or skin issue.

Outcome:

AH demonstrated operational competence with the ability to turn the wheelchair on/off and operate seating functions. She was able to drive the wheelchair independently indoors and appropriately switch between speeds in several different environments AH was able to perform pressure relieving weight shifts using a combination of power tilt/recline, demonstrate safe use of power recline and the AFP, navigate small spaces, and drive over various terrain and up/down ramps.

AH stated that her pain was decreased, and overall comfort improved with the independent ability to open her hip angle and elevate her lower extremities. She was able to demonstrate appropriate return to upright for functional tasks/completion of ADLs. AH was able

to return to her residence in the power wheelchair and the supplier took back the manual tilt-in-space.

Issues Related to Practice, Policy, and Research

The field faces significant gaps in literature concerning the long-term outcomes associated with the provision of seat functions, as well as in comparative analyses of different clinical models for their delivery. This lack of research leaves practitioners and policymakers with limited guidance on best practices and the long-term efficacy of various interventions. Moreover, there is a pressing need for more studies that explore the effects of policy decisions and funding mechanisms on user outcomes. Understanding how these factors influence access to, and the quality of, seat functions is critical for developing equitable and effective service delivery models. Addressing these research gaps could lead to improved clinical practices, better resource allocation, and more informed policy decisions that ultimately enhance the quality of life for individuals relying on seat functions for mobility and health maintenance.

Triggers of New Findings that Would Require an Update of the Position

The emergence of a newly published, formal scientific meta-analysis with robust evidence would necessitate an update to the current Position. Such a meta-analysis would offer a more comprehensive and statistically rigorous synthesis of existing research, potentially leading to new insights or stronger conclusions that could impact clinical practice, policy, or the provision of seat functions. However, at present, the literature is not sufficiently developed to support the undertaking of a formal, scientific meta-analysis. This limitation underscores the need for continued research efforts to build a more substantial body of evidence. As new studies are conducted and published, particularly those that employ rigorous methodologies and large sample sizes, the foundation for such a meta-analysis may be established. When this occurs, it

would provide a critical impetus to reassess and update the Position to ensure that it reflects the most current and best-available evidence, thereby maintaining its relevance and utility for clinicians, policymakers, and individuals with disabilities.

Relation of this Position Paper to the other Position Papers

This Position Paper serves as an update to the previously published paper on the same topic, offering expanded details on seat functions for enhanced clinical application. Individuals with mobility-related disabilities may, at times, benefit from consulting additional RESNA White Papers to ensure comprehensive clinical guidance and safety.

Summary of the Position Paper Development

This Position paper was developed through RESNA's Special Interest Group in Seating and Wheeled Mobility. The authors of this manuscript are clinicians and researchers experienced in the field of AT, and specifically, the seat functions discussed in this manuscript. A working group was established from RESNA members and clinicians interested in this topic who volunteered to serve on the revision committee.

The literature review was completed using several databases to find the most relevant, up-to-date resources that would correspond to each area of function/performance addressed in the previous paper's section "Overview of Current Literature." The research team met to develop a PICO-style research question (Population-Intervention-Comparison-Outcome), with the final string of search terms developed from the PICO question being used to gather articles from PubMed, CINAHL, and Ovid (See Figure 1 in Appendix). Articles that were published between 2014 and 2022 were included, as the most recent articles cited in the previous position paper were published in 2013.

When applicable, filters for peer-reviewed literature and literature published in English were applied during the search as well. PubMed yielded 1,239 results, CINAHL yielded 123, and Ovid yielded 608. After deduplication, 1,240 were left, which were then screened by the team based on the titles, then abstracts, then full text. The screening process was done collaboratively using RefWorks as the citation manager. Ultimately, 69 articles were included in the first-round of the full-text screening, and the final number of articles included in the paper from the search was 14.

Once the updated position paper was drafted, it became clear that some areas of function/performance were less represented in the pool of articles yielded by the search. For example, most of the articles included information on pressure management. It was determined that additional background literature would be gathered through individual searches and made exempt from the screening process to best support the clinical purpose of the paper, including articles published before the 2014 cut-off date that offered additional insights if they were not included in the last Position paper. Additionally, relevant articles used in previous versions of this Position paper were kept if no high-quality evidence was published more recently on the individual topic.

Upon completion of the draft and review by each author, the Position update was sent to SIG review by two content-area experts in the summer of 2023. A draft manuscript was posted on the RESNA website, allowing the authors to reflect on feedback provided and incorporate relevant perspectives into the update. The process for Position paper development, review, and approval is discussed further in the Procedures for the Development and Approval of RESNA Position Papers on Clinical Practice available at www.resna.org.

RESNA, the Rehabilitation Engineering and Assistive Technology Society of North America, is the premier professional organization dedicated to promoting the health and well-being of people with disabilities through increasing access to technology solutions. RESNA advances the field by offering certification, continuing education, and professional development; developing AT standards; promoting research and public policy; and sponsoring forums for the exchange of information and ideas to meet the needs of our multidisciplinary constituency. Find out more at www.resna.org.

Direct all correspondence to:

Jillian Kenderish, MOTR/L, ATP/SMS

Magee Rehabilitation Hospital

Jefferson Health Systems

jillian.stamatelos@jefferson.edu

References

Arledge, S., Armstrong, W. (2011) *Wheelchair Service Provision Guide* [White Paper]. Rehabilitation Engineering and Assistive Technology Society of North America.

*Benjapornlert, P., Kagaya, H., Inamoto, Y., Mizokoshi, E., Shibata, S., & Saitoh, E. (2020). The effect of reclining position on swallowing function in stroke patients with dysphagia. *Journal of Oral Rehabilitation*, *47*(9), 1120–1128. https://doi.org/10.1111/joor.13037

Bowers, D., Morgan, K., Abbott, L. R., Fishleigh, L., Cousins, A. L., & Taylor, R.

(2020). User perceptions of powered wheelchair functions. *Technology, Mind, and Behavior, 1*(2). https://doi.org/10.1037/tmb0000011

*Campeau-Vallerand, C., Michaud, F., Routhier, F., Archambault, P. S., Létourneau, D., Gélinas-Bronsard, D., & Auger, C. (2019). Development of a Web-Based Monitoring System for Power Tilt-in-Space Wheelchairs: Formative Evaluation. *JMIR Rehabilitation and Assistive Technologies*, *6*(2), e13560. https://doi.org/10.2196/13560

Chen, Y., Wang, J., Liu, L., & Li, S. (2010). *Comparative effects of different posterior tilt sitting postures on buttock pressure in children.* Paper presented at the 2010 3rd International Conference on Biomedical Engineering and Informatics (BMEI).

*Chen, Y., Wang, J., Lung, C. W., Yang, T. D., Crane, B. A., & Jan, Y. K. (2014). Effect of tilt and recline on ischial and coccygeal interface pressures in people with spinal cord injury. *American Journal of Physical Medicine & Rehabilitation*, *93*(12), 1019–1030. https://doi.org/10.1097/PHM.0000000000000225

*De Souza, L. H., & Frank, A. O. (2020). Clinical functions of electric powered

indoor/outdoor wheelchair users with spinal cord injuries: A cross-sectional study. *Assistive Technology*, *32*(3), 117–124. https://doi.org/10.1080/10400435.2018.1503205

Dicianno, B. E., Arva, J., Lieberman, J. M., Schmeler, M. R., Souza, A., Phillips, K.,Betz, K. L. (2009). RESNA position on the application of tilt, recline, and

elevating leg rests for wheelchairs. *Assistive Technology, 21*(1), 13-22.

*Dicianno, B. E., Lieberman, J., Schmeler, M. R., Souza, A. E. S. P., Cooper, R., Lange, M., Liu, H., & Jan, Y.-K. (2015). Rehabilitation Engineering and Assistive Technology Society of North America's Position on the Application of Tilt, Recline, and Elevating leg rests for Wheelchairs Literature Update. *Assistive Technology 27*(3), 193–198. EBSCO. https://doi.org/10.1080/10400435.2015.1066657

*Dolan, M. J., Bolton, M. J., & Henderson, G. I. (2019). Comparison of seating, power characteristics and functions and costs of electrically powered wheelchairs in a general

population of users. *Disability and Rehabilitation: Assistive Technology*, *14*(1), 56–61. https://doi.org/10.1080/17483107.2017.1393701

Frank, A. O., De Souza, L. H., Frank, J. L., & Neophytou, C. (2012). The pain experiences of powered wheelchair users. *Disability and rehabilitation*, *34*(9), 770–778. https://doi.org/10.3109/09638288.2011.619620

Fujita, D., Mori, A., Cleminson, T., Kada, M., Fukuda, J., Kobara, K., Watanabe, S. (2010). Using Seating Techniques as a Preventative Measure against Lower Limb Edema-The Effect of Combining Tilt Angle and Reclining Mechanisms on Wheelchairs. *Journal of Physical Therapy Science*, *22*(4), 437-441.

Giesbrecht, E., Ethans, K., & Staley, D. (2011). Measuring the effect of incremental angles of wheelchair tilt on interface pressure among individuals with spinal cord injury. *Spinal cord*, *49*(7), 827-831.

*Harrand, J., & Bannigan, K. (2016). Do tilt-in-space wheelchairs increase occupational engagement: a critical literature review. *Disability and Rehabilitation: Assistive Technology*, *11*(1), 3–12. https://doi.org/10.3109/17483107.2014.932021

Jan, Y.-K., Jones, M. A., Rabadi, M. H., Foreman, R. D., & Thiessen, A. (2010). Effect of wheelchair tilt-in-space and recline angles on skin perfusion over the ischial tuberosity in people with spinal cord injury. Archives of physical medicine and rehabilitation, 91(11), 1758-1764.

Kittelson, T., Kittelson-Aldred, A., Justad, J. M., Hoffman, L. A., & Coombs, N. C. (2024). *The Montana Postural Care Project: A pilot study implementing posture care management in a rural, low-resource region. Heliyon*. https://doi.org/10.1016/j.heliyon.2024.e31752

Liu, H.-Y., Cooper, R., Kelleher, A., & Cooper, R. A. (2013). An interview study for developing a user guide for powered seating function usage. *Disability and*

Rehabilitation: Assistive Technology, *9*(6), 499–512. https://doi.org/10.3109/17483107.2013.860633

Makhsous, M., Priebe, M., Bankard, J., Rowles, D., Zeigler, M., Chen, D., & Lin, F. (2007). Measuring tissue perfusion during pressure relief maneuvers: insights into preventing pressure ulcers. The Journal of Spinal Cord Medicine, 30(5), 497.

Osborne, L. J., Gowran, R. J., & Casey, J. (2023). Evidence for 24-hour posture management: A scoping review. *British Journal of Occupational Therapy*, *86*(3), 176-187.

Park, U. J., & Jang, S. H. (2011). The Influence of Backrest Inclination on Buttock Pressure. *Annals of Rehabilitation Medicine*, *35*(6), 897-906.

*Rauf, W., Sarmad, S., Khan, I., & Jawad, M. (2021). Effect of position on gross motor function and spasticity in spastic cerebral palsy children. *Journal of the Pakistan Medical Association*, *71*(3), 801–805. https://doi.org/10.47391/JPMA.1213

*Rice, L. A., Yarnot, R., Mills, S., & Sonsoff, J. (2019). A pilot investigation of anterior tilt use among power wheelchair users. *Disability and Rehabilitation: Assistive Technology, 16*(2), 152–159. https://doi.org/10.1080/17483107.2019.1644676

Schofield, R., Porter-Armstrong, A., & Stinson, M. (2013). Reviewing the literature on the effectiveness of pressure relieving movements. Nursing Research and Practice, 2013, 1-13. http://dx.doi.org/10.1155/2013/124095.

*Shankar, S., Mortenson, W. B., & Wallace, J. (2015). Taking Control: An Exploratory Study of the Use of Tilt-in-Space Wheelchairs in Residential Care. *The American Journal of Occupational Therapy, 69*(2),

6902290040. https://doi.org/10.5014/ajot.2014.013565

Sim, S., Jin, S., (2021). Hamstring stretching significantly changes the sitting biomechanics. *International Journal of Industrial Ergonomics*, 84, 103163. https://doi.org/10.1016/j.ergon.2021.103163

Sonenblum, S. E., & Sprigle, S. (2010). *Blood flow and pressure changes that occur with tilt-in-space.* Presented at the RESNA Annual Conference. 2010, Las Vegas, Nevada.

Titus, L. C. (2013). *How power tilt is used in daily life to manage sitting pressure:*

Perspectives of adults who use power tilt and therapists who prescribe this

technology. The University of Western Ontario electronic thesis and dissertation

repository. http://ir.lib.uwo.ca/etd/1321/.

*Titus, L. C., & Miller Polgar, J. (2018). Reasons for using power tilt: perspectives from users and therapists. *Disability and Rehabilitation: Assistive Technology, 13*(2), 132–139. https://doi.org/10.1080/17483107.2017.1299803

*Titus, L. C., & Miller-Polgar, J. (2021). To tilt or not to tilt; the decision-making

process. *Disability and Rehabilitation: Assistive Technology, 16*(1), 63–71. https://doi.org/10.1080/17483107.2019.1632943

Ward, A. L., Sanjak, M., Duffy, K., Bravver, E., Williams, N., Nichols, M., & Brooks, B. R. (2010). Power wheelchair prescription, utilization, satisfaction, and cost for patients with amyotrophic lateral sclerosis: preliminary data for evidence-based guidelines. *Archives of Physical Medicine and Rehabilitation, 91*(2), 268-272.

Wecht, J. M., & Harel, N. Y. (2013). Cardiovascular autonomic dysfunction in spinal cord injury: epidemiology, diagnosis, and management. *Journal of Neurotrauma*, *30*(17), 1411-1425. doi: 10.1089/neu.2012.2747.

* Wu, Y. K., Liu, H. Y., Kelleher, A., Pearlman, J., & Cooper, R. A. (2016). Evaluating the usability of a smartphone virtual seating coach application for powered wheelchair users. *Medical Engineering & Physics, 38*(6), 569–575. https://doi.org/10.1016/j.medengphy.2016.03.001

*Wu, Y. K., Liu, H. Y., Kelleher, A., Pearlman, J., Ding, D., & Cooper, R. A. (2017). Power seat function usage and wheelchair discomfort for power wheelchair users. *The Journal of Spinal Cord Medicine, 40*(1), 62–69. https://doi.org/10.1080/10790268.2016.1192360

Yoshikawa, M., Nagakawa, K., Tanaka, R., Yamawaki, K., et al. (2019). Improper sitting posture while eating adversely affects maximum tongue pressure. *Journal of Oral Rehabilitation, 46*(7), 630-636. doi: 10.1111/joor.12794.

*Indicates article is from literature search (See Appendix Figure 2)

Appendix

Figure 1: Search Terms

PICO Question: “How can power seating functions reduce secondary complications while promoting function/independence/participation?”

Population	Intervention	Outcome
All patients using PWCs	Power seating functions	1) Complication reduction 2) Independence/participation
Search Terms		
Spinal cord injury Tetraplegia Quadriplegia Stroke Cerebrovascular accident Cerebral palsy Traumatic brain injury Spina bifida Neurological conditions	Power mobility Power seating Power tilt Anterior tilt Posterior tilt Power recline Power height adjustable footplates Power leg rest Articulating leg rest	Activities of daily living Instrumental activities of daily living Basic activities of daily living Participation Independence Well-being Bladder management Bowel management Pressure sores Pressure injuries Pressure management Edema Contractures Quality of life

Final String of Search Terms

((((spinal cord injury) OR (tetraplegia) OR (quadriplegia) OR (stroke) OR (cerebrovascular accident) OR (cerebral palsy) OR (traumatic brain injury) OR (spina bifida) OR (neurological condition) OR (muscular dystrophy) OR (wheelchair))) AND (((power mobility) OR (power seating) OR (power tilt) OR (anterior tilt) OR (posterior tilt) OR (tilt) OR (power recline) OR (recline) OR (power height adjustable footplates) OR (power leg rest) OR (articulating leg rest) OR (seat backrest angle)))) AND ((("activities of daily living") OR ("instrumental activities of daily living") OR ("basic activities of daily living") OR (participation) OR (independence) OR (well-being) OR ("bladder management") OR ("bowel management") OR ("pressure sore") OR ("pressure injury") OR ("pressure management") OR (edema) OR (contracture) OR (posture) OR ("quality of life")))

Figure 2: Screening Process Flow Chart