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Rehabilitation Engineering and Assistive Technology Society of North America

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## RESNA Position on the Application of Seat Elevation Devices for Power Wheelchair Users Literature Update 2019

Rehabilitation Engineering & Assistive Technology  
Society of North America

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# **RESNA Position on the Application of Seat- Elevation Devices for Power Wheelchair Users Literature Update (2019)**

## **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-provision-guides> for a complete description of this procedure. Key aspects of this procedure include:

1. Establishment of a Work 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 of 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.

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## **1) Introduction**

### **a) Purpose**

The purpose of this paper is to share typical clinical applications as well as provide evidence from the literature supporting the application of power seat elevation devices. It is not intended to replace clinical judgment related to specific client needs. Power seat elevation devices address several medical needs. The scientific literature cited here supporting this critical component on a wheelchair has been drawn from research conducted with wheelchairs and ergonomic chairs, and in participants with and without disabilities.

A Rehabilitation Engineering & Assistive Technology Society of North America (RESNA) Position Paper is an official statement by RESNA. Position Papers are not intended to be formal, scientific meta-analyses. Rather, they use evidence and expert opinion to summarize best practices for Assistive Technology (AT) devices, evaluation, and service delivery. Position Papers provide a rationale for decision-making and professional skills for practitioners; and explain the medical necessity of AT devices and services for policy makers and funding sources.

### **i) Definitions**

(1) A power seat elevation (Waugh & Crane, 2013) device is a seat function component of a wheelchair that raises and lowers users while remaining in a seated position through the use of an electromechanical lift system to provide varying amounts of vertical seat to floor height. It does not change the seated angles or the seat's angle relative to the ground. A seat elevation device may

elevate vertically from a standard seat height or may lower the user closer to the (Arva et al, 2004) floor.

(2) A power elevating seat (PES) is another term used to describe this seat elevation feature.

(3) Power adjustable seat height (PASH) is another term used to describe a seat elevation device.

## **ii) Background**

Wheelchair mobility is often only considered from the perspective of people moving from one point to another on a two-dimensional plane (Arva et al., 2004). Vertical movement is necessary for people to function and participate in a three-dimensional world. A common intervention that provides vertical mobility within a wheelchair is a seat elevation device. It is RESNA's position that a power seat elevation device is a medically necessary critical component of a power wheelchair (PWC) for individuals who require a change in sitting height in the course of performing or participating in one's activities of daily living (ADLs) in all settings and environments.

## **b) Statement of Position**

### **i) The Position**

Seat elevation is a seat function that can be operated as a power component on PWC's. The beneficial effects of this seat function are numerous and have been reported in the previous Statement of Position Paper on this subject (Arva et. al, 2004). The purpose of this manuscript is to update this RESNA Position on the

application of seat elevation devices with more current and additional scientific literature.

It is RESNA's position that power seat elevation devices are medically necessary, as this technology enables certain individuals to:

- Facilitate reach biomechanics, safety and range
- Improve transfer biomechanics, safety and independence
- Enhance visual orientation and line-of-sight
- Support physiological health, safety and well-being.
  - Decrease hyperlordotic position of the neck
  - Promote stable seated positioning
  - Reduce symmetric tonic neck reflex (STNR) activity
  - Improve safety with performance/participation in ADLs.
- Promote communication, social engagement, self-esteem and integration.
- Improve wheelchair pedestrian safety.

A licensed, certified medical professional (i.e. physical or occupational therapist) should be involved with the assessment, prescription, trials and training in the use of the equipment to maximize safe use and functioning from the power seat elevation device. It is recommended this critical component be provided by an AT professional with the knowledge, skills and training in the provision of PWC's and power seating options such as an accredited supplier that employs a RESNA-certified Assistive Technology Professional (ATP) who specializes in wheelchairs and who has direct, in-person involvement in the wheelchair selection.

## **ii) Populations and Subpopulations Affected**

Those who may benefit from recommendations in this position are potential or current users of seat elevation devices as a power function. Those who are not appropriate for using this seating component would not benefit from the recommendations.

**iii) Precautions, Contraindications or Limits of Use**

- (1) Cognitive limitations which would prohibit safe use of the component.
- (2) Special precautions must be exercised when utilizing power seat elevation devices to avoid the risk of injury, such as impacting a surface if the wheelchair is under this surface during elevation.

**c) Relevance of Position**

**i) RESNA and Constituencies**

This paper may have implications on various RESNA related activities and could be used in several ways.

- (1) It could serve as a guide to practitioners in the evaluation, recommendation and justification for the provision of power seat elevation devices.
- (2) It could be used as a tool in academia to guide education in AT related fields of practice.
- (3) It could be utilized as a source of support material when there is a need to justify its medical benefits and necessity and provide advocacy for this power seat function.
- (4) It could be used as a clinical teaching tool for education of the wheelchair user and other team members.



(5) It could be used to provide evidence in an organized educational format to assist with policy changes and role definition related to power seat elevation devices.

(6) It could be used as a contribution to the development of a professional standard of practice.

(7) It could be used to promote further research on the medical benefits of this power seat function.

## **ii) Significance to Society**

This paper may have implications to society, including users of (AT). It could be used to guide education to consumers about the use of this power seat function to improve their general knowledge and ability to self-advocate for procurement of this critical component. It could also be used to impact public policy related to coverage and reimbursement.

## **2) Rationale for the Position**

### **a) Overview of the Current Literature**

#### **i) Facilitate Reach Biomechanics, Safety and Range**

According to the World Health Organizations (WHO) International Classification of Functioning, Disability, and Health (ICF), reach can be associated with activities and participation under the codes d4106 (mobility, shifting the body's centre of gravity), d4452 (mobility, reaching), and d6404 (domestic life, storing daily necessities).

Access to the vertical environment is essential for a wheelchair user to perform or participate in their ADLs. As stated in the Wheelchair Skills Training Program (WSP) Manual, "skill in wheelchair use is not an end itself, it is a means to an end" (Kirby et al., 2018). The manual further asserts, "the characteristics of the

wheelchair, its features, fit and setup can have major effects on skill performance.” It should be noted that “the skills chosen for inclusion in the Wheelchair Skills Program are intended to be representative of the range of skills that wheelchair users and/or caregivers may need to regularly perform,” such as reaching.

Reaching a high object is included in the WSP because “a combination of upward and sideways or forward reaching is often needed when reaching for a light switch, elevator button or cupboard.” The target for the test is 2.5 cm (1 in.) in diameter and 1.5 m (60 in.) from the floor. To pass the test “the subject reaches up under control, touches the target and then resumes the normal sitting position.” Chair height, and the ability to reposition the seat height, can have an impact on the wheelchair user’s ability to touch the target. Passing the reach test is only the first step in assessing whether an individual can actually reach to perform or participate in their ADLs from the wheelchair (Kirby et al., 2018).

In a survey conducted by Georgia Tech (2017), 100 of 105 (95.2%) respondents indicated that they use their seat elevation device “often” or “sometimes” to help reach objects. (Table 1) However, the activities in which they are engaged while elevated, such as moving, dressing, grooming, eating/meal preparation, toileting and bathing, differ. The survey did not delineate why people perform activities at different seat heights, but wheelchair users report seat elevation devices on their PWC reduces the effect of environmental barriers to the vertical space.

|                      | Often | #  | Sometimes | #  | Rarely | # | Never | # |
|----------------------|-------|----|-----------|----|--------|---|-------|---|
| To help reach things | 81.9% | 86 | 13.3%     | 14 | 3.8%   | 4 | 1%    | 1 |

|   |       |    |       |    |       |    |       |    |
|---|-------|----|-------|----|-------|----|-------|----|
| While dressing                                      | 16.3% | 17 | 26%   | 27 | 17.3% | 18 | 40.4% | 42 |
| While grooming (brushing teeth, combing hair, etc.) | 39.4% | 41 | 23.1% | 24 | 16.3% | 17 | 21.2% | 22 |
| While eating or preparing a meal                    | 59.2% | 61 | 24.3% | 25 | 6.8%  | 7  | 9.7%  | 10 |
| During toileting activities                         | 27.2% | 28 | 17.5% | 18 | 22.3% | 23 | 33%   | 34 |
| During bathing activities                           | 21%   | 22 | 10.5% | 11 | 17.1% | 18 | 51.4% | 54 |

Table 1

Access to the vertical environment is essential for a wheelchair user to perform or participate in their ADLs. By convention the height of objects with which an individual must interact on a daily basis may be as follows:

Kitchen countertop height = 36 in.

Kitchen upper cabinet height = 54 in. at the bottom, 84 in. at the top

Freezer height = 50 in. – 72 in.

Stove top height = 36 in.

Over stove microwave height = 50 in. – 54 in. at the bottom, 66 in. at the top

Height for a closet rod = 66 in., top shelf = 80 in.

Washer/Dryer height = 36 in., stacked = 75 in.

Height of a light switch = 48 in.

Height for a thermostat = 60 in.

Fire alarm pull height = 42 in. – 54 in.

When compared to the mean shoulder height in sitting for women (n=2208) at 21.87 in. and men (n=1774) at 23.53 in. in a standard chair (Gordon et al., 1988), it is clear seated individuals must reach above shoulder height to access any of these areas of the home. Anthropometric measurements also show that the mean vertical grip reach in sitting for the same women is 47.73 in. (43.01- 52.32 in.) and 51.57 in. (46.36 – 56.38 in.) for men, which falls short of the heights needed to safely perform or participate in many ADLs, even at the top range of the reach. This may place seated individuals, such as PWC users, at risk for injury and increased healthcare costs from adverse occurrences in their quest for independence.

Requejo et al. (2008) compared the frequency and duration of overhead arm activity between wheelchair users and occupationally matched non-wheelchair users during an 8-hour workday. They found that non-wheelchair users performed an average of 53 (9 – 88) episodes of overhead arm activity while wheelchair users performed an average of 297 (44 – 798) episodes of arm activity during the same time period. The total time spent in an overhead position was five times greater for wheelchair users (mean = 34.6 min., range = 7.9 to 106.6 min.) as compared to standing adults (mean = 6.6 min., range = .4 – 15.5 min.). As a result, they assert that it is imperative for wheelchair users to “minimize extreme or potentially injurious positions at the shoulder by avoiding extreme positions such as hand over the shoulder.” They also state, “based on ergonomics literature, there is a strong association between working above overhead height and shoulder pain in the work environment” and that “use of a wheelchair increases a person’s need for overhead activity to access the environment.”

Requejo et al. (2008) conclude the increased overhead arm use documented in the study “may contribute to the development of shoulder pathology” and “individuals with [spinal cord injury] (SCI) should avoid extreme shoulder positions, particularly overhead arm activities.” Extrapolated out, any wheelchair user that reaches overhead 297 times/day x 365 days/yr. will reach overhead 542,025 (80,300 – 1,456,350) times during the 5-year reasonable useful lifetime of the PWC. During the same 5 years a person at standing height that reaches overhead 53 times/day x 365 days/yr. will only reach overhead 96,725 (7,300 – 160,600) times. While the study evaluated only individuals with SCI, this information may be applicable for other individuals with disabilities who use a PWC.

Sabari et al. (2016) state that “the upper limb and neck are common sites for the development of repetitive strain injuries (RSI)” and hypothesized that “the addition of a seat elevating device may alleviate the risk factors that lead to the development of RSI.” They observed 60 ambulatory adults age 18 – 65, seated symmetrically in a PWC who were asked to perform a functional vision task and a functional reach task. Each task was performed at the minimum wheelchair seat height and the maximum seat height. Results “revealed a statistically significant difference between AROM (active range of motion) required for shoulder abduction to complete the reaching task, when comparing performance with the wheelchair at minimum seat height and at maximum seat height.” They contend “the power seat elevator at its maximum height may allow wheelchair users to perform functional tasks without excessive [end range movement] AROM at the shoulders, thereby decreasing their risk for developing RSI.” While “further investigation would need to test a sample population

of long-term wheelchair users,” they conclude that their “findings provide preliminary support for considering [seat elevation] as a medical necessity for wheelchair users who are at risk of developing chronic pain syndromes associated with the shoulder girdle and/or cervical spine.”

According to Schiappa et al. (2017), power seat elevation devices also have a significant impact on the quality of life of end users. Three groups were compared using the Functional Mobility Assessment (FMA) score on reaching during the procurement of a new power mobility device:

- 1) with a seat elevation component, compared to their current device which did not have one;
- 2) without a seat elevation component, compared to their current device that did have one; and,
- 3) with a seat elevation component, compared to their current device which had one.

The change in score was significantly different between the first two groups indicating a that a PWC equipped with a seat elevator is associated with higher satisfaction with ability to reach.

In its publication, *Preservation of Upper Limb Function following Spinal Cord Injury (SCI): Clinical Practice Guidelines for Health-Care Professionals (2005)* the Paralyzed Veterans of America (PVA) recommends providing “seat elevation ... to individuals with SCI who use PWC’s and have arm function”. It further states, “even if modification to both the home and work environments are so complete as to totally negate the need for overhead activities, the individual with SCI will still be

forced to do them whenever they shop, visit the post office, or check out books at the library”.

It is likely that a person who uses a PWC with a low, static seat height will need to reach overhead as many times as a person in a manual wheelchair (MWC) but will have a difficult time executing it. In evaluating individuals with disabilities for the appropriate mobility base, if a MWC is reasonable and necessary, the expectation is that the individual has sufficient balance, strength, range of motion, coordination, endurance and upper extremity (UE) function to self-propel and perform or participate in their ADLs. According to expert opinion this may also include the ability to reach overhead as many times per day as necessary.

In summary, power seat elevation devices can increase vertical reach for increased function in all environments where the PWC is used. In addition, by increasing seat height, less active vertical reach is required for many tasks which can reduce risk of injury and pain in the neck, shoulders and UE's.

## **ii) Improve Transfer Biomechanics, Safety and Independence**

According to the WHO ICF, transferring can be associated under Activities and Participation under codes d420 (mobility, transferring oneself) and d429 (mobility, changing and maintaining body position).

“Transferring from a wheelchair to other surfaces such as a bed, toilet, or other surface is a necessary part of the daily routine. Transferring from a wheelchair to another surface such as a bed or toilet is essential to enable individuals to perform their ADLs. Since transfers are necessary for an individual to perform their ADLs, they should be “considered a medical necessity” (Arva et al., 2009). In a survey conducted by Georgia Tech (2017), 84 of 105 respondents (80%) indicated that they

used the power seat elevation device “often” or “sometimes” during transfers to or from the wheelchair.

Wheelchair users must transfer a minimum of twice each day, yet Kim, Her and Ko (2015) found that “among the basic ADL, transfer is a task that is performed by each patient 15 – 20 times per day, on average.” Regardless of the method used, the ability to adjust the height of the seat, in conjunction with transfer training using an appropriate method and proper technique, is an essential component for independent, safe and efficient transferring to/from the wheelchair.

Sitting pivot transfer (SPT) is the most common transfer method using the UE’s (Kim et al., 2015). In fact, wheelchair users with absent or significantly impaired use of their lower extremities “must use their UE’s for almost all activities of daily living (ADLs), such as getting in and out of bed, transferring to a shower or toilet, and transferring in and out of a car” (Tsai et al., 2014).

Sit-pivot transfers are one of the most strenuous wheelchair activities performed, and incorrect transfer skills may predispose wheelchair users to developing upper limb pain and overuse related injuries, such as rotator cuff tears, elbow pain and carpal tunnel syndrome (Tsai et al., 2014). Kim et al. (2015) not only report “pain prevalence rates [of] 58.5%; shoulder: 71%, elbow: 35%, wrist: 53%, hand: 43%”, they also state that SPT is “the most burdensome task for the musculoskeletal system, the nervous system and the cardiovascular system among wheelchair related ADL.”

Kim et al. (2015) “compared the changes in trunk and shoulder angles and reaction forces under each hand at two different seat heights in 18 unimpaired males



during independent sitting pivot transfer. They found significant increases in the trunk angles of forward and lateral flexion, even though rotation decreased while transferring in the lower hand direction. Increased shoulder flexion, anterior/posterior forces and reduced lateral forces were also shown. Hence, placing the hands of the supporting arms lower than the seat position during sitting pivot transfer was identified as having biomechanical advantages.” They suggest that the results of the study “can be applied as guidelines for effective and safe methods for ...spinal cord injury patients’ SPT and can be utilized as reference data when considering the appropriate heights of aids for wheelchairs.”

Clinical evaluation and observation should take into consideration UE, core and lower extremity strength, range of motion, muscle tone and balance when determining the difference between the seat height of the wheelchair and the height of the surface to be transferred to or from.

Tsai et al. (2014) evaluated whether using proper transfer skills as measured by the Transfer Assessment Instrument (TAI) is associated with reduced loading on the UE’s in 23 wheelchair users who performed transfers to a level-height bench while a series of force plates, load cells and a motion capture system recorded the biomechanics of their natural transferring techniques. While Part 1, item 5 of the TAI states, “the subject performs a level or downhill transfer, whenever possible” the study removed the height differential and had all participants perform level transfers to validate that the TAI is an effective tool for evaluating transfers on a 15-point scale. The study concluded that, “the transfer skills that can be measured by the TAI are closely associated with the magnitude and timing of joint movements.

As such, the TAI may be useful for measuring the effects of a training intervention on upper limb joint loading.” This may include the recommendation of a seat elevating device for PWC users who must perform level or downhill transfers.

Wang et al. (1994) also explored the joint reaction forces and muscle activity changes attributed to transferring from a wheelchair to three different height surfaces. Six able bodied males between the ages of 20 and 25 performed transfers from wheelchairs to heights below, equal to, and above the chair. Surface electrodes collected the EMG activation during these transfers. This study also demonstrated that transferring to higher surfaces resulted in greater muscle force requirements than did transfers to equal surfaces or lower surfaces. This again stresses the importance of the ability to change seat height to reduce the repetitive stress associated with transfers.

A sit-to-stand (STS) movement, which is defined as a movement of standing up from a chair to an upright posture, is a frequently performed ADL according to Yoshioka, Nagano, Hay, & Fukashiro (2014). They found that “community dwelling people stand up from a [standard] chair approximately 60 times each day.” However, “many people with weakness, pain, or other disabilities of the lower extremities have difficulty rising from a standard seat height” (Burdett, Habasevich, Pisciotta & Simon, 1985).

Janssen, Bussmann & Stam (2002) performed an extensive review of literature from 1980 – 2001 (n=39) on STS movement. They report the “minimum height for successful rising ... appears to be 120% of lower leg length” and “lowering the height of the seat makes the STS movement more demanding or even unsuccessful.”

Hence, attempting to transfer from a seat height that is too low may be associated with an increase in fall risk.

While a minimum chair height standing (MCHS) ability test has been shown to be effective as a fall risk-screening instrument for older individuals (Reider, 2012), the research did not include individuals with disabilities or those who use PWC's.

Yoshioka et al. (2014) examined "the large range of seat heights on peak joint moments of the lower limbs during STS movement" using 8 healthy, young subjects. They were studied standing up from seat heights of 10 cm (3.93 in.), 20 cm (7.87 in.), 30 cm (11.81 in.), 40 cm (15.7 in.), 50 cm (19.68 in.), and 60 cm (23.62 in.). The study confirmed that, "the peak mechanical load and the peak knee to hip joint movements increase inversely to seat height within the range of high to normal seat height (60 to 40 cm)." The study concludes that "the findings are useful for the design of chair [and] the improvement in the evaluation standard of minimum STS height tests." Therefore, the ability to adjust the wheelchair seat height at a minimum of 20% more than an individual's specific lower leg length, and even higher for individuals with muscle weakness, can minimize overall LE loads and range of motion required for this repetitive task.

Nakamura, Nagasawa, Sawaki, Yokokawa & Ohira (2016) cite previous studies that report "the vastus lateralis, rectus femoris, and tibialis anterior muscles showed a tendency towards higher activity levels with decreasing seat height" and indicate "standing up from a lower seat height would be more demanding." To confirm this, they examined "the effect of different seat heights on peak oxygen uptake (peak VO<sub>2</sub>) during incremental STS exercise" with 13 healthy young women. "The seat

heights were adjusted to 100%, 80%, 120%, and 140% of knee height distance.”

They found that peak VO<sub>2</sub> on the incremental STS test increased as seat height decreased.” This may have significant implications for individuals who are aging with a disability, and/or exhibit respiratory compromise as a result of their diagnosis or disability.

Schiappa et al. (2017) also found power seat elevation devices have a significant impact on the satisfaction of end users related to transfers. The same three groups were compared using the FMA score on transferring during the procurement of a new power mobility device with a seat elevation component compared to their current device which did not have one, FMA score on transferring during the procurement of a new power mobility device without a seat elevation device compared to their current device having one, and FMA score when being able to maintain a power seat elevation device during the procurement process. Again, the first and second groups show significantly different FMA scores, indicating a difference in satisfaction with transfer ability when their power wheelchair was equipped with a seat elevation device or not.

Clinically, when evaluating stand-pivot transfers, every STS transition can be split into four main phases: flexion (leaning forward), momentum-transfer (seat-off), extension (coming to the upright position) and stabilization (standing) according to Janssen et al. (2002). This is followed by pivoting or stepping and the stand-to-sit transition. While STS transfers have been widely studied, there is a significant lack of information concerning stand-to-sit transfers, especially at varying seat heights.

In summary, the ability to change the seat height of the wheelchair in relation to the height of the surface being transferred to can improve transfer biomechanics and efficiency, increase safety, reduce injury and fall risk and promote or maintain independence.

### **iii) Enhance Visual Orientation and Line of Sight**

Numerous studies support the benefits of direct eye contact on both human interaction with others and on the environment. Eye contact can have a positive impact on memory, improve socialization and stimulate cognition (Schreiber et al., 2016; Oda et al., 2011; Conty et al., 2016). Direct eye contact may provide a means for processing the intentions of communication as well as contributing to non-verbal communication (Jiang et al., 2017). Level, horizontal gaze improves interactions with the environment which, in turn, improves safety through obstacle avoidance (Diebo et al., 2016).

People seated in wheelchairs are positioned at a lower level than their standing counterparts, which forces an upward gaze to achieve direct eye contact. When interacting with the environment at a seated height, people are forced to maintain an upward gaze in an attempt to visualize many items or events in their home and community. This upward gaze may not be sufficient for certain visual tasks such as seeing into cabinets or on shelves, observing items cooking on a stovetop, utilizing a mirror for grooming and hygiene (shaving, brushing teeth, etc.), and reading information that is secured to a wall (thermostats, menus, maps, calendars, etc.). Use of a seat elevation device provides the required line of sight for these activities. In

addition, line of sight improves eye contact with media for learning and is associated with higher performance in school (Volmink et al., 2015).

Sabari et al. (2016) observed 60 ambulatory adults seated in a PWC who were asked to perform a functional visual task and a functional reach task at minimum wheelchair seat height and at the maximum seat height, using a seat elevating device. They found a “statistically significant difference between AROM requirements for cervical extension to complete the computer viewing tasks, when comparing performance with the wheelchair at minimum seat height and at maximum seat height ( $t = 15.318$ ,  $p < 0.001$ ) (Sabari et al., 2016)”. These hyperextended cervical positions may lead to fatigue and pain.

Promoting communication, social engagement, self-esteem and integration is affected by line of sight as stated in Conty et al. (2016) which reports “a long tradition of research in social psychology indicating that eye contact induces many types of favorable evaluations of others.” Referred to as the Watching Eyes (WE) effect, they assert that direct gaze activates self-referential processing, which leads to an increased understanding of the interaction in relation to self. In fact, “because vision is the dominant sense in humans, and because only direct gaze leads to eye contact, direct gaze has a stronger power than the other modalities of social contact.” By stimulating increased attention towards social situations and interactions, WE effects may have a positive impact on “human cognition, enhancing memory and self-awareness, promoting pro-social behavior, and increasing likability of others.” In addition, direct gaze has been reported to increase self-esteem and minimize cognitive decline. For individuals with disabilities who used power mobility devices the

addition of a seat elevation component may facilitate the therapeutic benefits derived from the WE effects, stimulate communication, social interaction and integration.

In summary, seat elevation devices can improve visual orientation and line of sight which can provide direct eye contact for memory, socialization, cognition, communication and even safety in navigation. Improved line of sight reduces cervical hyperextension commonly seen in people seated at a typical wheelchair height.

#### **iv) Support Physiological Health, Safety and Well-being**

Wu, Y., Lie, H., Kelleher, A., Pearlman, J., Ding, D. & Cooper, R.A. (2017) assert that “wheelchair discomfort is a very common problem for wheelchair users” and suggest that “increasing the frequency of using PSFs (power seat functions) may decrease wheelchair discomfort.” The chairs used in the study were outfitted with encoders “to record angle changes for tilt, recline, legrests and seat elevation.” The 13 individuals with disabilities that completed the 8-week study in their home and community filled out the Tool for Assessing Wheelchair discomfort (TAWC) each day. The results showed that “wheelchair discomfort intensity is correlated with the frequency of using tilt, recline and legrest functions” and the frequency of using these functions “were not correlated with each other.” While the study does not discuss what impact power seat elevation devices may have on discomfort, it does state “wheelchair discomfort might result from other medical or physiological factors and the maximal improvement of wheelchair comfort that PSFs can achieve should be further investigated.”

Clinical observation of wheelchair users sitting at a low seat height highlights the fact that they are forced to extend the cervical spine to levels that contribute to pain when interacting with other people or objects in their environment.

Many people who sustain an upward gaze tend to hyperextend the neck. The cervical position required to maintain an upward gaze has physical consequences. Diebo et al. (2016) concluded that cervical lordosis (neck hyperextension) is needed to maintain even a horizontal eye gaze in people with increased thoracic kyphosis. Wheelchair users with neurologic and orthopedic impairments frequently have increased kyphosis, which could lead to a tendency toward cervical lordosis. Access to a seat elevation device to achieve horizontal eye gaze for the aforementioned benefits would minimize cervical lordosis and resultant pain Kirby, R.L., Fahie, C.L., Smith, C., Chester, E.L., & Macleod, D.A. (2004) studied 20 wheelchair users who assumed and maintained four neck positions for 5 minutes each to determine if they experienced more discomfort in an extended or rotated position as compared to their self-selected most comfortable position (MCP). “The MCP for wheelchair users is straight ahead with the neck slightly flexed.” However, to make eye contact with the average height seated male, the wheelchair user had to extend their cervical spine  $11^{\circ}$ . Cervical extension increased to  $27^{\circ}$  when looking up at an average height standing male. They conclude “sustained extension and rotation of the neck, alone or in combination, increase the neck discomfort of wheelchair users” and contend “these findings have implications for wheelchair design”.

Sabari et al. (2016) suggest “frequent hyperextended cervical positions are likely to lead to fatigue of the soft tissue structures of the cervical region, and significant



discomfort can be expected when these positions are sustained.” Results of their study “reveal a statistically significant difference between AROM requirements for cervical extension to complete the computer viewing tasks, when comparing performance with the wheelchair at minimum seat height and at maximum seat height.” They state that their study findings “provide support for the potential benefit of a seat elevation device in reducing the arcs of motion required to extend the neck, and thereby minimizing the risk for RSI at the neck.” Their data supports “previous recommendations that wheelchair users of all physical statures may benefit from the various advantages of a power seat elevation device, especially in minimizing the risk for the development of pain in the neck and secondary complications” such as cervical myelopathy.

In expert opinion, adverse implication of neck hyperextension that may be observed in individuals who look up from a low seat height is the elicitation of the symmetric tonic neck reflex (STNR). The STNR is triggered by flexion or extension of the neck. When the neck flexes, the arms flex and the legs extend; conversely when the neck extends, the arms go into extension and the hips and legs flex. This may result in a loss of seated position, and discomfort in individuals with cerebral palsy who have retained the STNR, or in individuals that have suffered a stroke or traumatic brain injury where the STNR has re-emerged. Unfortunately, there is no research that has looked at the effect a symmetric tonic neck reflex has on seated position, discomfort in the seated position as a result of an STNR, or whether the application of a power seat elevating devices minimizes the effect of an STNR on posture by maintaining a neutral neck position. However, observing and detailing the

impact of seat elevation for the one person being evaluated for a PWC is what is ultimately required to establish the medical need for this critical component.

In summary, when a person is positioned with the neck hyperextended, this can lead to fatigue, pain and even the elicitation of the STNR. Power seat elevation devices can reduce neck hyperextension by improving line of sight through increasing seat height.

**v) Improve Wheelchair Pedestrian Safety**

Following the results of their study, Kraemer, J., & Benton, C. (2015) call for a priority of policy changes related to disability accommodations for pedestrians who use wheelchairs. Their study was designed to describe and quantify the fatal pedestrian crashes among persons using wheelchairs in the USA from 2006 to 2012. Two sources were used to provide a capture-recapture analysis. A descriptive analysis of the fatal crashes was also conducted. The capture-recapture analysis utilized data of fatal crashes that were recorded by the National Highway Traffic Safety Administration (NHTSA) Fatality Analysis Reporting System, and the LexisNexis US newspaper database. For the capture-recapture estimation the fatal crashes in the two registries were matched.

A comparison of pedestrian death risk in the general US population (determined by the Centers for Disease Control and Prevention (CDC) fatal injury report database) was calculated in relation to the rate of fatalities in the wheelchair pedestrian population. The results indicate that pedestrians using wheelchairs have about a one-third higher risk of mortality when compared to the overall pedestrian population.

Further descriptive analyses of the circumstances surrounding the accidents identified that the “low conspicuity of wheelchair users appears to play a large role in the risk of mortality. This finding is consistent with the finding that 75% of the crashes involved no driver avoidance maneuvers. The results indicate that pedestrians using wheelchairs have about a one-third higher risk of mortality when compared to the overall pedestrian population. Further descriptive analyses of the circumstances surrounding the accidents identified that the “low conspicuity of wheelchair users appears to play a large role in the risk of mortality. This finding is consistent with the finding that 75% of the crashes involved no driver avoidance maneuvers.

The authors summarize the disparity in safety for pedestrians using wheelchairs compared to the normal population and recommend incorporating disability accommodations into disability infrastructure, including persons who use wheelchairs.

#### **vi) Evidence of Use**

In a recent study designed to evaluate how people use a seat elevating device in their everyday life, instrumentation was placed on 24 PWC’s with seat elevators to measure wheelchair occupancy, seat height, in-seat activity level and bouts of mobility (Sonenblum et al., 2019), 453 days of seat elevation and mobility data was collected. Time in chair, # of transfers (in and out), # of times seat elevated, center of pressure movement, amount of time spent in the elevated positions and # of times seat elevated >9” were among the variables studied. “The average day included a mean (SD) of 8.4 (4.9) hours in the wheelchair. During the average day participants

transferred 8.5 (6.0) times in and out of their wheelchair. On average, participants elevated their wheelchair 3.9 (4.4) times per day, with an average of 1.0 (1.6) elevation per day extending past 9". Ten participants used their wheelchair in an elevated position every single day of the study, while the remaining 14 had at least one day in which they did not use the elevating component. However, the study documented 1,943 events in which participants elevated their seat above 1". 16 of 24 (67%) participants transferred while elevated at least one time during the study. Most transfers took place at heights less than 5" or greater than 9", and 14 people changed their seat height between the transfer out of the wheelchair and the return transfer at least one time. They reported reach and gaze (line of sight) as being the most often purpose for elevation. Across all days and seat heights, participants had a frequency of active segments 17.7 (25) times per hour they were seated in their wheelchair. Comparing the in-seat activity level while elevated to those when the chair was below 1"; however, shows an increased in-seat activity level while elevated (diff = 42.6 (341.8) per hour" insinuating that the participants experienced increased reach access when elevated. In addition, "23 of 24 participants wheeled while elevated", although few reported using the seat elevator for the purpose of mobility. Overall there was a high variability within and across subjects which is consistent with other measures of wheelchair use. Participants varied from using this critical component on a daily basis to more intermittent, but it still provided a functional benefit to their daily lives.

## **vii) Case Examples**

### **Josh**

Josh was diagnosed with Limb-Girdle Muscular Dystrophy at the age of 8. At age 25, he presents with poor strength in all 4 extremities and poor to fair core strength. He has poor sitting balance and does not have the ability to perform a sit-pivot or sliding board transfer. His standing balance is also poor and he is non-ambulatory; however, by standing with his hips and knees hyperextended he is able to “lock” the joints and use the structural integrity of his ligaments to do a stand-pivot transfer independently while holding on to the armrests of the chair.

With the wheelchair seat elevated to 31”, Josh is still able to perform a stand-pivot transfer independently to and from his bed, which is also elevated to 31” regardless of whether he is in his own apartment or in his old room at his parent’s house. At any lower seat height, he is fully dependent on a personal care attendant to transfer. In addition, Josh also remains fully independent in managing his bladder needs as he is able to stand from his wheelchair at a seat height of 31” to use the toilet.

### **Madonna**

Madonna sustained an incomplete spinal cord injury at the T10 level at age 18. She used a MWC for 35 years but at 53, as she ages with a disability, she began experiencing significant pain and strength limitations in her neck, shoulders and upper back from overuse injuries. As a single parent, she found herself reaching overhead hundreds of times each day to cook, clean and do laundry from a low, static seat height, exacerbating her pain. In addition, she sustained third-degree burns twice while removing a hot, cooked item from the stove due to the poor biomechanical position of her UE’s from a low seat height. Madonna has now used a

PWC with a seat elevation component for more than 2 years, reports a significant reduction in UE pain and no adverse occurrences. She attributes this to adjusting her wheelchair seat to the appropriate height for the task she is performing, thereby saving thousands of dollars in medical care.

### **Lisa**

Lisa is a 30-year-old graphic designer with arthrogyriposis and contractures of her arms and legs. Her elbows are contracted in extension and she does not have shoulder strength to raise her arms to shoulder height. She therefore performs many tasks with her mouth. She uses a seat elevation device to raise her seat height so that she can perform tasks with a mouth stick, such as operating her microwave, using a keyboard on a podium during presentations, adjusting her thermostat, and accessing elevator buttons. She also uses the seat elevation device when transferring into bed. With the seat height adjusted to the same level of her bed she is still able to perform 50% of the transfer.

### **Mary**

Mary is a 60-year-old woman with inclusion body myositis. Her strength has declined such that she relies on a mechanical lift for safe, dependent transfers. Her husband is her primary caregiver. He has back issues. To significantly reduce risk of injury to her during the transfer process he elevates the chair to its full height to place her in an uncompromised position and get into and out of the wheelchair safely. This critical component eliminates the need for patient care assistance (PCA) for transfer needs. For Mary it also saves the healthcare system thousands of dollars

as 1 hour of PCA, at \$15/hour x 365 days per year would otherwise cost a minimum of \$5475 annually.

### **Mark**

Mark was born with cerebral palsy. He is fully independent in all his activities of daily living at the wheelchair level even though he presents with spasticity in all four extremities. When Mark looks up from a low seated position, he elicits a significant STNR that triggers spasticity and involuntary movement that results in him flexing his legs (right greater than left) and extending his arms (left greater than right). This causes him to lose his positioning in the wheelchair and appropriate contact with his cushion and back, which can result in injuries, especially on the seated surface, due to shearing forces. In addition to the discomfort it causes him, this reflexive response also negatively impacts his ability to reach and function to perform his ADLs throughout the day.

### **Kiel**

Kiel sustained an incomplete spinal cord injury at the C5/6 level. In addition to an increased risk for shoulder and neck RSI, Kiel has a critical use for his power seat elevation system as he reaches and adjusts the thermostat in his home. Kiel experiences thermoregulatory dysfunction secondary to his spinal cord injury. Thermoregulation is the process that allows the human body to maintain its core temperature. Thermoregulatory dysfunction in individuals with SCI refers to the fact that their body cannot perform this function properly. As a result, Kiel needs to be able to adjust the thermostat independently for his health and safety.

While he can reach the thermostat at a height of 48" from a low, static seat height,

he is unable to see what temperature he has adjusted it to without the capability of adjusting the height of his wheelchair seat. Vertical adjustment provides him the visual access he needs to support this reaching activity, independently manage this condition and not incur additional PCA hours or medical costs from an adverse occurrence.

### **Cathy**

Cathy is a 4<sup>th</sup> grader (9 years old) with spina bifida. She is a full-time PWC user and uses power seat elevation to perform age-appropriate tasks and activities at home, school and in the community. During a trial of the PWC, that included power seat elevation, she made a list of what she could do with this critical component, as opposed to what she could not do, or needed assistance to do without it. Most important for Cathy was the ability to reach the sink to wash her face and brush her teeth, see herself in the mirror to do her hair, reach the buttons on the school elevator, order and pay for lunch in the cafeteria, access the table for experiments in science class, reach books in the library and access supplies and the board in her classrooms, which eliminated the need for an aide. Not only is she able to get herself ready for school, she is also able to make herself a snack, do her daily chores and care for her pet guinea pig afterwards.

### **viii) Issues Related to Practice, Policy, and Research**

A dearth of literature exists on long term outcomes related to provision of seat functions and comparisons of different clinical models of their provision. While the preponderance of evidence supports the medical benefits of a power seat elevation



device as a component of a PWC more research on the impact of policy and funding on user outcomes remains.

## **b) Conclusion**

Power seat elevation devices allow an individual who uses a PWC to independently change their seat to floor height. Increasing seat height can increase functional reach (vertical and horizontal reaching ability) as well as decrease the amount of overhead reaching that is required (Katz-Leurer et al, 2009). Overhead reach can lead to injury and pain of the shoulder, neck and UE's. Changing the seat height in relation to other surfaces can increase transfer safety and efficiency as well as reduce injuries and fall risk. Seat elevation devices can also improve line of sight with others and with the environment. Without a more direct line of sight, individuals in wheelchair tend to assume cervical extension which can lead to fatigue, pain and even elicitation of an STNR. Power seat elevation devices are an important PWC seat function which can improve overall function; safety; efficiency; and reduce fatigue; injury; and pain to minimize the risk for adverse medical outcomes and resulting healthcare costs.

## **c) Limitations of the Current Literature**

Limitations of the current literature include small sample sizes, absence of high-level experimental randomized clinical trials, and lack of longitudinal data on medical outcomes.

### **i) Relation of this Position Paper to Previous Position Papers**

This Position Paper is an update of the previously published Position Paper (Arva et al., 2009). Triggers of new findings that would require an update of the position include a new published formal, scientific meta-analysis, would provide stronger evidence than this Position and would require an update of the current

Position. However, at this time insufficient literature exists to conduct a formal, scientific meta-analysis. In relation to other position papers on component use, the use of power seat elevation in combination with additional critical components may improve the usability and function of the device as well as increase the quality of life for the individual.

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## **Appendices**

### **Summary of the Position Paper Development**

RESNA, 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](http://www.resna.org).

### **Detail of the Development and Review Process**

This Position Paper was developed through RESNA's Special Interest Group in Seating and Wheeled Mobility (SIG-09). The authors of this manuscript are clinicians and researchers experienced in the field of AT, and specifically, the seat function discussed in this manuscript. A working group was established from RESNA members interested in this topic who volunteered to serve on the Position Paper revision committee. Each member conducted a literature review of articles which were published since the previous Position Paper and indexed in Pubmed. The search included papers that evaluated individuals with disabilities and also control participants wherein the content was relevant to the effects of seating and positioning on body structures and function. The team compiled references into a complete bibliography which was then reviewed and summarized. Additional articles were found through reviewing the

bibliographies of individual manuscripts. This search identified articles which were not part of the original Position Paper. A draft manuscript was posted on the RESNA website, and the authors read and incorporated the comments that were posted. 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](http://www.resna.org).