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Impact of wheelchair seat height on neck and shoulder range of motion during functional task performance

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ABSTRACT
Wheelchair users are at high risk for developing repetitive stress injuries (RSI) of the cervical spine and glenohumeral joints due to increased demands on active range of motion (AROM) when performing functional tasks from a seated position. The addition of a seat elevation device may alleviate the risk factors that lead to the development of RSI. However, there are no studies which establish that wheelchair seat height impacts upon arthrokinematic requirements at vulnerable joints. Additionally, Medicare and most insurance carriers do not cover the cost of power seat elevators because this feature has not been shown to be a "medical necessity." This study examined differences in AROM at the cervical spine and glenohumeral joint during performance of two functional tasks while seated in a wheelchair with the seat elevation feature at minimum and maximum height. Results revealed statistically significant differences in AROM requirements for cervical extension and shoulder abduction between the two wheelchair seat heights. These findings provide preliminary support for the value of the power seat elevation function in minimizing the risk of RSI at the shoulder complex and cervical spine in wheelchair users.

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KEYWORDS
activities of daily living; mobility; positioning and support surfaces; seating; wheeled mobility aids

The upper limb and neck are common sites for the development of repetitive strain injuries (RSI). RSI are a constellation of musculoskeletal injuries caused by repetitive movements, awkward postures, and sustained force (Buckle & Devereux, 2002; Long, Bogossian, & Johnston, 2013; Van Tulder, Malmivaara, & Koes, 2007). Problems typically begin with mild symptoms of pain, fatigue, numbness, tingling, and stiffness that rise and dissipate depending on activity demands. These initially minor symptoms have the potential to develop into debilitating disorders such as shoulder impingement syndrome, frozen shoulder, shoulder tendinitis, thoracic outlet syndrome, and tension neck syndrome (DiCecco, 2010). Repetitive overhead activities have been linked to muscle fatigue and subsequent abnormalities in kinematics at the scapulothoracic and glenohumeral joints (Ebaugh, McClure, & Karduna, 2006; Neumann, 2010). Repetitive hyperextension of the neck is associated with a reduction in the diameter of the vertebral canal and can be a risk factor for cervical myelopathy, especially in people with spinal stenosis (Neumann, 2010).

Individuals in wheelchairs must perform daily functional activities from a seated position, in which their heads, necks, and arms are at lower heights as compared to a person who is standing. When interacting with other people or with objects in the environment, wheelchair users are forced to extend the cervical spine to levels that contribute to neck and shoulder pain (Boninger et al., 2003; Kirby, Fahie, Smith, Chester, & Macleod, 2004) and which could lead to chronic orthopedic impairments in the cervical spine. In a study examining neck discomfort among wheelchair users, participants reported that they were most comfortable when their necks were held in a slightly flexed position, and yet they had to extend their cervical spines by 11° to look at the average seated male and 27° in order to make eye contact with the average height standing male (Kirby et al., 2004). 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.

When reaching for objects in home or work environments, wheelchair users must contend with general architectural designs that favor individuals who are functioning in a standing position. Excessive, repetitive movements through a wide arc of motion at the glenohumeral joint, particularly beyond 60° of abduction, are associated with the development of chronic orthopedic impairments, including shoulder impingement, that may ultimately lead to serious injury, such as rotator cuff tear (National Institute for Occupational Safety & Health, 1997; Requejo et al., 2008). Rotator cuff tear in persons with spinal cord injuries is associated with lost capacity to follow skincare regimens and live independently at home (Paralyzed Veterans of America, 2005).

Studies have established that manual wheelchair users are at significant risk of developing shoulder muscle fatigue and pain due to the demands of wheelchair propulsion (Dalyan,

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Supplemental data for this article can be accessed here.

Cardenas, & Gerard, 1999; Mercer et al., 2006). Although power wheelchairs reduce soft tissue demands associated with manual propulsion, power wheelchair users are likely to develop upper limb deconditioning and experience muscle fatigue during everyday activities (Hastings, Robins, Griffiths, & Hamilton, 2011; Paralyzed Veterans of America, 2005). The combination of muscle fatigue and performance of repetitive overhead tasks may potentially lead to kinematic changes at joints within the shoulder girdle (Ebaugh et al., 2006) and is an early risk factor for the development of RSI (Lomond & Côté, 2011).

A study comparing the frequency and duration of overhead arm activity between wheelchair users and occupationally matched non-wheelchair users during an 8-hour workday found that wheelchair users performed an average of 297 episodes of overhead arm activity, while the controls performed an average of 53 episodes. Thus, the total time spent in an overhead position was five times greater for wheelchair users as compared with standing adults (Newsam et al., 2007). In tissue that is already fatigued, without adequate time to recover from recent stress, these repetitive overhead movements are likely to lead to the development of RSI (National Institute for Occupational Safety & Health, 1997). The ability to adjust wheelchair seat height may help minimize the repetitive excessive motions that cause stress to soft tissues at the neck and shoulder girdles.

Minimum wheelchair seat heights vary between manufacturers (see Table 1), with a range of 16″–19″ (40.64–48.26 cm). Power seat elevators vary in the extent to which they allow a power wheelchair user to change his seat level, with a range of 6″–12″ (16.24–30.48 cm) in elevation from minimum seat height (see Table 1 for detailed information and references). Functional benefits include the ability to retrieve objects at greater heights, which facilitates independence in activities of daily living related to hygiene, meal preparation, parenting, and shopping (Ding et al., 2008). Individuals may also gain the ability to perform specific work and school related activities. Psychologically, the ability to achieve eye contact with others provides for enhanced communication, social engagement, self-esteem, and perceived quality of life (Rohde, Bonder, & Triolo, 2012). Power seat elevators also provide physical benefits and the Rehabilitation Engineering and Assistive Technology Society of North America (RESNA) holds the position that seat elevators are medically necessary for some wheelchair users (Arva, Schmeler, Lange, Lipka, & Rosen, 2009). However, Medicare does not fund this feature because it classifies wheelchair seat elevation devices as a "convenience item" (Centers for Medicare Services, 2015). Because of this classification, many individuals who might benefit from wheelchair seat elevation devices are denied the use of this important feature.

One physical benefit is that the ability to adjust one's seated height helps people avoid repeated excessive motions that are related to repetitive stress to soft tissue at the neck and shoulder girdles. However, there are no studies which definitively establish that wheelchair seat height impacts upon arthrokinematic requirements at the cervical spine and glenohumeral joint.

Table 1. Standard and maximum seat heights for power seat elevation products.

Manufacturer and Website	Wheelchair Model/Seating System Model	Minimum seat Height (in./cm from floor)	Maximum Seat Height (in./cm from floor)	Elevating Mechanism/Height
Permobil; www.permobilus.com	F3	17.5 in./44.45 cm	29.5 in./74.93 cm	Scissor, 12 in./30.48 cm
Permobil; www.permobilus.com	M300 and C350 with Corpus Seating System	17.5 in./44.45 cm	25.5 in./64.77 cm	Center mount, 8 in./20.32 cm
Quantum Rehab; www.quantumrehab.com	Q6 Edge 2.0 with TRU-Balance 3 iLevel 10″ Lift	17.5–19.5 in./44.45–49.53 cm	27.5–29.5 in./69.85–74.93 cm	Scissor, 10 in./25.4 cm
Quantum Rehab; www.quantumrehab.com	Q6 Edge X with TRU-Balance 3 10″ Lift	18–20 in./45.72–50.8 cm	28–30 in./71.12–76.2 cm	Scissor, 10 in./25.4 cm
Quantum Rehab; www.quantumrehab.com	Rival with TRU-Balance 3 10″ Lift	18.5–20.1 in./46.99–51.05 cm	28.5–30.1 in./72.39–76.54 cm	Scissor, 10 in./25.4 cm
Sunrise Medical; www.sunrisemedical.com	QM-7 Series	16 in./40.64 cm	28 in./71.12 cm	Scissor, 12 in./30.48 cm
Motion Concepts; www.motionconcepts.com	Rovi X3 Maxx	17 in./43.18 cm	29 in./73.66 cm	Scissor, 12 in./30.48 cm
Motion Concepts; www.motionconcepts.com	Multiple Base Options/F Series	16.5 in./41.91 cm	21.5–23.5 in./54.61–59.69 cm	Center [ost, 5–7 in./12.7–17.78 cm
Motion Concepts; www.motionconcepts.com	Multiple Base Options/Ultra Low Maxx	16.75 in./42.55 cm	21.75–23.75 in./55.25–60.33 cm	Center post, 5–7 in./12.7–17.78 cm
Invacare; www.invacare.com	FDX & Storm Series Torque/Formula	17.75 in./45.09 cm	24.75 in./62.87 cm	Center post, 7 in./17.78 cm
Invacare; www.invacare.com	TDX/Formula	18.5 in./46.99 cm	25.5 in./64.77 cm	Center post, 7 in./17.78 cm

Note. Detailed web links are provided in a supplementary file. This table was limited to products for power wheelchairs that would be reimbursed in the Medicare Group 3 code.

Our goal was to examine the impact of wheelchair seat height on active range of motion (AROM) requirements at the cervical spine and shoulder complex during functional task performance. We hypothesized that (1) use of a seat elevator at maximum height, compared to lower height, will be associated with lower AROM requirements at the neck and shoulder to complete functional tasks; and (2) shorter torso length and standing height will be associated with greater differences in AROM needed to perform tasks at the two seat heights.

Methods

Design

This observational study used a within subjects design to examine the impact of wheelchair seat height on AROM requirements for cervical extension and shoulder abduction in a group of ambulatory adult participants during a functional vision task and a task requiring functional reach. We also examined the relationship between physical stature (standing height and torso length) and the impact of seat height on AROM requirements. Ethical clearance for this study was granted through the Institutional Review Board at SUNY Downstate Medical Center.

Participants

To avoid the risk of harm to individuals with disabilities and satisfy Institutional Review Board (IRB) requirements, a convenience sample of 63 ambulatory adults between the ages of 18–65 was recruited through flyers posted in a university setting. Inclusion criteria were (1) no self—reported pain in the neck, spine, or right shoulder; (2) self-reported ability to accurately see the images in the functional vision task. Following enrollment, three participants were excluded from data collection because they were unable to reach the target in the functional reach task from the minimum seat height position. The final sample included 60 participants.

Procedures

Subjects were seated symmetrically in the power wheelchair. They were instructed to wear any eyewear that typically assists them with functional vision. They were then asked to complete two tasks: a functional vision task and a task requiring functional reach. Subjects performed each task under two conditions: (1) minimum wheelchair seat height—17.5″” (44.45 cm) from seat pan to floor, and (2) maximum seat height—25.5″ (64.77 cm) from seat pan to floor.

All testing was administered in a designated space in which markings on the floor and adjacent walls ensured consistent positioning of the wheelchair and task objects. We determined the markings based on the functional field of vision (69.5″; 176.53 cm) and functional reach (63.5″; 161.29 cm) of one of the investigators whose standing height was 73″ (185.42 cm). To avoid any possibility that the testing sequence might affect outcomes, half of the participants began the tasks at the minimum seat height and half began the tasks at the maximum seat height.

For Task 1, a functional vision task, the front wheel of the wheelchair was placed 9.5″ (24.13 cm) from a cabinet (18.0″ × 36.0″ × 64.5″ [45.72 cm × 91.44 cm × 163.83 cm]). The wheelchair was centered 6.5″ (16.51 cm) from either side of the cabinet. A computer tablet was placed at the center on top of the cabinet. Participants were asked to view the computer monitor to determine whether a series of slides with images were matched or not matched. A visual image, such as a flower, and a descriptive word, such as tulip, was a match, whereas an image of a sailboat with the word tiger was a mismatch. The center of the image was 69.5″ (176.53 cm), based on the functional field of vision of the investigator previously mentioned. This task was based on a procedure used in a published study of neck discomfort in wheelchair users (Kirby et al., 2004). Its purpose was to ensure that participants maintained their necks in extension for the duration of the measurements.

Participants began with their head and eyes in a neutral position, so that the tester could align the goniometer appropriately. They were then asked to look up at the display by maintaining a central gaze and engaging their neck muscles to move their head. The participants began the task once this position was assumed. Participants were asked to indicate each time a mismatch was presented by pressing the horn located on the right armrest of the power wheelchair. Their thumbs were placed over the horn button prior to the start of the task to ensure they did not need to come out of position to find the button during the task. To maintain consistency, each participant was presented with six matched and six mismatched images.

For Task 2, a functional reaching task, the right side of the wheelchair was placed 14″ (35.56 cm) from the wall. The front wheel was placed 19.5″ (49.53 cm) from the center of a Jelly Bean switch mounted 63.5″ (161.29 cm) above the floor on the participant’s right side. The Jelly Bean switch was plugged into the adaptive interface, PowerLink4 Control Unit, along with an alarm-clock radio (Ablenet, 2015b). The radio was placed on a table next to the wheelchair. Stickers were placed on the bony landmarks of each participant, corresponding to the alignment of the fulcrum and proximal and distal arms of the goniometer. Participants were asked to raise their right index fingers, touch the yellow sticker on the Jelly Bean switch, and keep the radio activated. The purpose of the task was to ensure that participants maintained their right shoulders in abduction for the duration of the measurements.

Unlike clinical goniometric assessment, which measures a person’s total capacity for active motion at a joint, we measured the AROM required to complete the study tasks. For the reaching task, subjects with shorter arm spans maintained their elbows at full extension. As in a natural context, subjects with wider arm spans flexed their elbows during task performance, thus reducing the AROM required at the shoulder complex to complete the task.

During Tasks 1 and 2 a researcher aligned the goniometer according to standard procedures (Norkin & White, 2009; Reese & Bandy, 2009; Sabari, Maltzev, Lubarsky, Liszkay, & Homel, 1998) for assessing AROM of cervical extension and shoulder abduction. The goniometer scale was masked to the data collector and an assistant read and recorded the data.

Materials

The study was performed using a Permobil C300 power wheelchair with a Permobil Corpus Ergo cushion and an 8″ (20.32 cm) power seat lift. Seat depth was 18″. The minimum and maximum seat heights were 17.5″ (44.45 cm) and 25.5″ (64.77 cm) from the seat pan to the floor, respectively. AROM was measured with an 8″ (20.32 cm) goniometer made by Prestige Medical. The cervical extension task required the use of a 10.6″ (26.92 cm) computer tablet (Windows Surface RT 64 GB Model 1516, screen resolution: 1,366 × 768). For the shoulder abduction task, a 5″ (12.7 cm) Big Red Jelly Bean switch (Ablenet, 2015a) was adapted to activate an alarm-clock radio using the PowerLink4 Control Unit (Ablenet, 2015b). With this configuration, subjects could turn on the radio and keep it on as long as they depressed the switch. A yellow sticker was placed at the center of the Jelly Bean switch as a target for participants to press. Stickers were also used to mark designated landmarks, corresponding to the lateral epicondyle and acromion of each participant, and the back support of the power wheelchair to ensure consistent alignment of the goniometer during the shoulder abduction task. A wall-mounted height chart and yard stick were used to measure each participants' standing height and torso length (i.e., measurement from seat pan to the acromion of each participant while seated in the power wheelchair), respectively.

Data collection

Each subject participated in a single 10-minute session. The person's initials, sex, age, vision status, standing height, and torso length were manually recorded on a data collection sheet. After successful completion of each task, the cervical and shoulder AROM measurements were recorded in degrees. The data were then transcribed onto an Excel spreadsheet for statistical analysis using Statistical Package for the Social Sciences (SPSS).

Reliability of data collection

High intrarater reliability is reported for goniometric measurements in the seated position of both active shoulder abduction ($r = 0.97$; Sabari et al., 1998) and cervical extension ($r = 0.86$; Defibaugh, 1964). Similarly, high interrater reliability is reported for measurements of cervical extension ($r = 0.90$; Defibaugh, 1964), while fair interrater reliability is reported for measurements of shoulder abduction ($r = 0.69$; Hayes, Walton, Szomor, & Murrell, 2001).

One month prior to beginning the study, we determined intra-and-inter-rater reliability for three possible data collectors, with the goal of achieving intraclass correlation coefficients (ICCs) of $r \geq 0.8$. With the goniometer scale masked, and readings recorded by a second data collector, each researcher obtained goniometric measurements for two trials of active cervical extension and shoulder abduction for each participant in a sample of 10 volunteers who later participated in the study. For each measurement, the tester aligned the goniometer according to a standard procedure for cervical extension (Reese & Bandy, 2009) and shoulder abduction in a seated position (Norkin & White, 2009; Sabari et al., 1998). An assistant read the goniometric scale and recorded the data in degrees. These techniques were utilized during the actual investigation as well.

ICCs between the three raters were in the moderate range for cervical extension ($r = 0.581$) and shoulder abduction ($r = 0.813$); but the analysis revealed strong intra-rater reliability for cervical extension ($r = 0.932$) and shoulder abduction ($r = 0.974$). We structured the testing sessions so that the rater who achieved the highest level of intra-rater consistency for cervical extension collected all data for cervical extension and the rater who achieved the highest level of intra-rater consistency for shoulder abduction collected all data for shoulder abduction. A third data collector read the goniometer and recorded all measurements.

Data analysis

Descriptive statistics were used to determine demographic and physical characteristics of the sample (see Table 2).

The paired samples *t*-test was used to compare the AROM requirements for cervical extension and shoulder abduction under the two height conditions and to determine if there was a statistically significant difference between (1) AROM requirements for cervical extension at the minimum seat height and maximum seat height and (2) AROM requirements for shoulder abduction at the minimum wheelchair seat height and maximum seat height.

We calculated the difference scores between AROM requirements for cervical extension and shoulder abduction at minimum and maximum seat heights and then used Pearson product-moment correlation coefficient analyses to

Table 2. Descriptive statistics: demographic data, range of motion (ROM) requirements, and differences in AROM between the two seat heights

	Minimum	Maximum	Mean	*SD*
Age (years)	19	55	28.18	7.32
Standing height	61 in./154.94 cm	76 in./193.04 cm	67.17 in./170.18 cm	3.63 in./9.21 cm
Torso length	19 in./48.26 cm	23.5 in./59.69 cm	21.44 in./54.44 cm	1.2 in./3.06 cm
Cervical AROM, minimum seat height	11°	39°	24.38°	7.45°
Cervical AROM, maximum seat height	2°	36°	15.37°	6.93°
AROM difference score between the two seat heights, cervical extension	−0.5°	19.0°	9.01°	4.56°
Shoulder abduction AROM, minimum seat height	60°	113°	85.11°	13.95°
Shoulder abduction AROM, maximum seat height	35°	82.5°	53.39°	9.58°
AROM difference score between the two seat heights, shoulder abduction	20°	47.5°	31.72°	6.44°

determine if standing height and torso length were related to these difference scores.

Finally, we used the Sort and Filter feature in Excel to examine the data for AROM requirements in both tasks. Our goal was to determine the frequencies for which very high levels of AROM were required when the wheelchair was at minimum seat height as compared to when participants performed the task at maximum seat elevation.

Results

Participants

Our sample consisted of 60 participants ($N = 60$), with 35 females and 25 males. Table 2 includes descriptive information about age, standing height, and torso length for the sample. Nineteen participants wore glasses; three of them wore progressive lenses.

Impact of seat height on ROM requirements for task performance

Results from a paired sample *t*-test revealed 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 ($t = 15.318$, $p < 0.001$). Table 2 provides descriptive data about AROM requirements at minimum and maximum seat heights.

Results from a paired sample *t*-test revealed a statistically significant difference between AROM required for shoulder abduction to complete the reaching task, when comparing performance with the wheelchair at the minimum seat height and at maximum seat height ($t = 38.177$, $p < 0.001$; see Table 2 for descriptive data).

Relationship between characteristics of physical stature and impact of seat height on AROM requirements

Pearson product-moment correlation analysis revealed a moderate and statistically significant inverse relationship between torso length and impact of seat height on AROM for shoulder abduction ($r = 0.589$; $p < 0.001$). Torso length was not related to impact of seat height on AROM requirements for cervical extension ($r = 0.034$; $p = 0.681$).

Pearson product-moment correlation analysis revealed a moderate-to-strong statistically significant inverse relationship between standing height and impact of seat height for shoulder abduction ($r = -0.689$, $p < 0.001$). Standing height was not related to impact of seat height on AROM requirements for cervical extension ($r = 0.047$, $p = 0.723$).

Frequency of AROM requirements associated with RSI

In the shoulder abduction task, at minimum wheelchair height, all participants (100%) needed to abduct the shoulder to ≥60°. Repetitive performance of shoulder abduction motion beyond 60° is an acknowledged risk factor for shoulder impingement and tendonitis (National Institute for Occupational Safety & Health, 1997). Only 12 (20%) required this degree of AROM to perform the task. Twenty-three participants (38% of the sample) needed to abduct the shoulder to ≥90° when performing the reaching task from minimum seat height. With the seat at maximal height, 82° was the maximum requirement for shoulder abduction to complete the functional task.

In the cervical task, 25 participants (42% of the sample) needed to extend the cervical spine to ≥27° when seated at minimum wheelchair height. With the seat at maximal height, only four participants (7% of sample) needed to extend the cervical spine to this extent. Thirteen participants (22% of sample) needed to extend the cervical spine to ≥31° at minimum seat height, while only one participant (2% of sample) needed to extend the cervical spine to ≥31° at maximal height. Those individuals who required greater arcs of motion were not necessarily those who had shorter standing height or torso length.

Discussion

Shoulder abduction

The study results supported our hypothesis that wheelchair seat height impacts upon AROM requirements for shoulder abduction during functional task performance.

When seated at the minimum wheelchair seat height, wheelchair users need a greater arc of motion at the shoulders to perform functional tasks, which may put them at higher risk for developing RSI. The power seat elevator at its maximum height may allow wheelchair users to perform functional tasks without excessive AROM at the shoulders, thereby decreasing their risk for developing RSI.

We found that physical stature contributed significantly to the impact of wheelchair seat height on AROM requirements for shoulder abduction for the reaching task. This is most likely due to differences in arm length, since individuals with longer arm lengths were able to flex their elbows to varying degrees during the reaching task. Arm span, defined as the distance from left fingertips to right fingertips when a person holds both arms at 90° abduction, is closely associated with standing height (Canda, 2009; Reeves, Varakamin, & Henry, 1996). This finding may indicate that, with regard to minimizing the risk of RSI of the shoulder girdle, the power seat elevation feature may be particularly important for wheelchair users of shorter stature. We recommend that clinicians use the arm span measurement as a feasible assessment that can yield consistent data for all clients, including those with significant disabilities, such as postural deformities.

Cervical extension

The study results confirmed our hypothesis that wheelchair seat height impacts upon AROM requirements for cervical extension during functional task performance. Based on these findings, we postulate that wheelchair users may require more AROM at the neck to perform daily functional activities while seated at the minimum wheelchair seat height. Over time, such wide arcs of motion at the cervical spine may contribute to the development of neck pain (Kirby et al., 2004).

We found that only four participants (7% of the sample) needed to extend the cervical spine greater than 27° when the wheelchair was positioned at maximum seat height. This finding adds preliminary empirical support that the use of a power seat elevator may decrease excessive kinematic demands on the cervical spine and help reduce the risk of developing RSI in wheelchair users. Overuse of the neck extensors may lead to mechanical neck pain, which may lead to disability (Cote, Cassidy, & Carroll, 2000) and potential functional limitations. Our study findings provide support for the potential benefit of a seat elevation feature in reducing the arcs of motion required to extend the neck, and thereby minimize the risk for RSI at the neck. The seat elevation feature also offers additional recognized psychosocial benefits such as eye-to-eye contact, increased participation, and improved self-confidence (Arva et al., 2009; Ding et al., 2008).

Our findings suggest that the physical characteristics of standing height and torso length are not related to the difference in AROM for cervical extension at the minimum and maximum seat heights. These data support 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 at the neck and secondary complications (Arva et al., 2009; Kirby et al., 2004), such as RSIs.

Limitations

The participants in this study were ambulatory adults between the ages of 18 and 65; thus, caution should be used in generalizing the findings to the population of long-term wheelchair users. Other limitations of this study related to the manner in which participants completed the tasks. While we attempted to control for compensatory movements and maintain the required position during task performance, there may have been instances during which participants adjusted their necks or trunks slightly. Additionally, during the cervical extension task, participants may have differed in the extent to which they moved their heads versus their eyes (Kirby et al., 2004). As with most manual measurements, there was some potential for human error during goniometric assessments and scale readings. We controlled for this by establishing high levels of intra-rater reliability and having our most reliable rater for shoulder abduction collect all data for the reaching task and our most reliable rater for cervical extension collect all data for the visual task. One assistant read and recorded the goniometric measurements for all participants.

Recommendations for future research

We recommend that future studies collect data for arm length, instead of standing height, since arm length would be the most feasible predictor, for actual wheelchair users, of potential impact of the power seat elevation feature on AROM requirements at the shoulder girdle. Similarly, we recommend including more participants who wear corrective eyewear, especially progressive lenses, to determine if individuals who wear eyeglasses experience greater requirements for cervical extension during visual tasks, as compared with others. Future research should examine other potential factors (e.g., neck length) that may impact upon cervical AROM requirements during tasks or social engagement with standing adults. Furthermore, it would be beneficial to investigate if wheelchair users of shorter height are more prone to the development of RSIs at the neck and shoulder, as compared to those who are taller. Most importantly, future investigations would need to test a sample population of long-term wheelchair users.

Conclusion

In addition to the psychological and functional values of the power seat elevation feature in power wheelchairs, this study's findings provide preliminary support for considering this feature as a medical necessity for wheelchair users who are at risk of developing chronic pain syndromes associated with the shoulder girdle and/or the cervical spine.

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