Reaching Performance Using a New Seat Design in Wheelchair Users with Spinal Cord Injury

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ABSTRACT

Study Design. Repeated measures on one group of Spinal Cord Injury (SCI) subjects in two sitting postures. **Objective.** To investigate the effect of sitting with a reduced ischial support and an enhanced lumbar support (**WO-BPS**) on upper extremity reaching performance in persons with SCI. **Methods**. Twelve wheelchair users with below C5-level SCI were recruited. Kinematics and muscle activity were recorded in two postural positions (**Normal** and **WO-BPS**) for upper extremity reaching tasks. **Results**. Compared with **Norma**l (flat backrest and flat seat) posture, sitting in **WO-BPS** posture did not significantly change the functional performance of the wheelchair users. **Conclusions.** Sitting with reduced ischial support and enhanced lumbar support do not affect the daily activity of the wheelchair.

KEYWORDS: wheelchair seating, stability, adjustability, comfort

BACKGROUND

In the U.S. alone, there are approximately 1.4 million individuals who use wheelchairs full time[1]. For these individuals, independence from the seated position is a primary concern. Among them, individuals with spinal cord injuries (SCI) at the cervical level have altered neuromuscular control, requiring seating devices which provide postural stability while permitting functional independence[2].

Reaching ability is a key component to maintaining high levels of independence in persons with SCI. An optimal wheelchair design will allow for the best possible mobility without sacrificing the safety of the user. Many studies have shown that changes in external support can be introduced into existing wheelchair designs without compromising reaching[3-6]. May et al.[7] found that increased lumbar support in some wheelchair designs did not negatively effect reaching in persons with SCI. However, studies have shown that changes to wheelchair design can significantly affect balance and the performance of reaching tasks of persons with SCI[3,5].

A new seat design, in which the back part of the seat (BPS) can be dynamically tilted downward with respect to the front part of the seat (FPS) to release the ischial-sacral pressure load in sitting, was proposed by Makhsous et al.[8]. It also includes an enhanced adjustable lumbar support to provide additional back support. Two postures are presented with the design. The **Normal** posture is when the BPS is even with the FPS and the lumbar support is flat. The **WO-BPS** (Without Back Part of Seat) posture is when the BPS is tilted down 20º with respect to the FPS and the lumbar support is fully engaged. The purpose of this study was to investigate whether the new sitting concept of WO-BPS had significant influence on reaching ability of the wheelchair users with SCI in the **Normal** and **WO-BPS** postures.

METHODOLOGY

Participants: The study was approved by the **Northwestern University Institutional Review Board**. Before participation all participants gave written informed consent. Twelve SCI patients (35.6±9.3 yrs; 82.8±14.4 kg; 172.1±11.3 cm, 11 male and 1 female) were tested.

Equipment for data acquisition: An instrumented wheelchair, of which the BPS can be tilted down, was used. The tilting angle of the BPS was controlled by a BASIC Stamp® (BASIC Stamp 2p, Parallax Inc.,

Rocklin, CA) processor based custom-made electro-pneumatic controller and had a range of motion of 20° downwards with respect to the FPS. The lumbar support was an air bladder that could be inflated/deflated via an air pump and also controlled by the same controller.

Position of the shoulder and arm were measured by a motion capturing system (Optotrak 3020, Northern Digital Inc., Waterloo, Canada) with infrared markers mounted on landmarks of the shoulder, upper arm, lower arm and wrist.

Muscle activity was recorded through surface EMG (Bagnoli-8, DelSys, Inc., Boston, MA) signals from the long head of triceps, biceps, anterior deltoid, upper trapezius, infraspinatus, serratus anterior, sternocleidomastoid, and pectoralis major during the reach. A ground electrode was placed at the spinal process of C7.

Reaching Tasks and Protocol: Reaching performance of the seated participant was evaluated through the reach-out distance and muscle activities during a set of reaching tasks which consisted of grabbing light weight balls from locations around the subject differing in distance, direction, and height. At each distance, lightweight foam balls were placed at 100%, and 120% of shoulder heights in the direction of straight ahead 0° and laterally 45° at three distances, i.e., arm length, maximal reach, and half-way in between arm length and maximal reach. Therefore, altogether 12 reaching tasks were performed for each participant. For each trial, five seconds were timed and counted out loud while the participant reached out and back for the ball in order to ensure a smooth, controlled motion. The participants were allowed a ten second rest before moving on to the next object. Upper limb movement and muscle activities were recorded simultaneously for each trial. Each task was performed in the **Normal** and **WO-BPS** postures.

RESULTS

All 12 participants successfully completed all reaching tasks.

Compared with **Normal** posture, sitting in **WO-BPS** posture did not significantly change the overall functional performance of the wheelchair users during the reaching tasks. Only 2 tasks out of the 12 tasks were seen to have significant differences in muscle activities between the 2 postures. One was the maximum reaching distance trial for 45° at the shoulder height, and the other was the reaching forward at middle distance at 120% of shoulder height. In both tasks, more efforts in the pectoralis major was required to perform the reaching ($P=0.034$ and $P=0.049$, respectively). For achieved reaching distance of the lower arm, there were significant difference found in 2 out of 12 tasks. One was the arm length reaching in forward direction at the shoulder height where in the WOBPS posture, the participants were able to reach farther of 175.0±230.4 mm ($P=0.023$). The other trial was the similar task but at a 120% shoulder height, when the participants in WOBPS posture were not able to reach as far as in Normal posture (124.9±171.8 mm less, $P=0.029$).

DISCUSSION

Given that most daily living activities involve upper body exertion, it is important to assess the reaching performance when adopting a new wheelchair design. This study investigated quantitatively the biomechanical effects of two seating postures. As for the upper extremities, our data showed minimal differences in muscle activity between the two postures. Results show that the tested posture does not produce significant change in upper extremity muscle activity during the majority of the reaching tasks. A reason as to the difference in pectoralis major activation we observed could be from having participants reach at end of their normal functional capabilities. Significant differences were only found in the activities of one muscle when reaching maximal distance and/or the maximal height. It is possible that participants' performance were altered due to the unfamiliarity of the chair coupled with the reaching distance.

Future research should be performed in order to find out if proper use of the new wheelchair modifies upper extremity use and leads to a decrease in upper extremity muscle recruitment therefore leading to a

more energy efficient movement pattern. Long term effects of upper extremity or posterior cervical pain should also be examined.

Possible limitations to this study include the fact that participants were asked but not confirmed of their height, weight, and ASIA level. Also, since this is a student research project, so there were seven experimenters who switched roles and responsibilities during the experimental procedures. This could have led to inter-observer differences when following protocols. Lastly, we have a small sample size which makes it more difficult to generalize our results to other SCI populations.

CONCLUSION

Preliminary results suggest that our novel seating system does not have a significant impact on reaching tasks in our SCI population.

REFERENCES:

1. Winslow, C. and J. Rozovsky, *Effect of spinal cord injury on the respiratory system.* American Journal of Physical Medicine and Rehabilitation, 2003. **82**(10): p. 803-14.
2. Baydur, A., R.H. Adkins, and J. Milic-Emili, *Lung mechanics in individuals with spinal cord injury: effects of injury level and posture.* J Appl Physiol, 2001. **90**(2): p. 405-11.
3. Aissaoui, R., et al., *Effect of Seat Cushion on Dynamic Stability in Sitting During a Reaching Task in Wheelchair Users With Paraplegia.* Arch Phys Med Rehabil, 2001. **82**: p. 274-81.
4. May, L.A., et al., *Wheelchair back-support options: functional outcomes for persons with recent spinal cord injury.* Archives of Physical Medicine and Rehabilitation. 2004; 85: 1146-1150, 2004. **85**: p. 1146-50.
5. Reft, J. and Z. Hasan, *Trajectores of target reaching arm movements in individuals with spinal cord injury: Effect of external trunk support.* Spinal Cord, 2002. **40**: p. 186-91.
6. Taylor, E., et al. *Performance of manual propulsion in wheelchair bound patients using a new seating design*. in *RESNA 27th International Conference*. 2004. Orlando, FL.
7. May, L.A., et al., *Wheelchair back-support options: functional outcomes for persons with recent spinal cord injury.* Archives of Physical Medicine and Rehabilitation. 2004; 85: 1146-1150, 2004. **85**: p. 1146-50.
8. Makhsous, M., et al., *Sitting with adjustable ischial and back supports: Biomechanical changes.* Spine, 2003. **28**(11): p. 1113-21.

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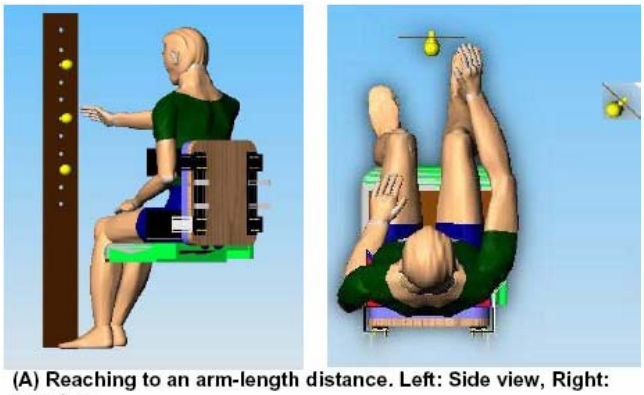
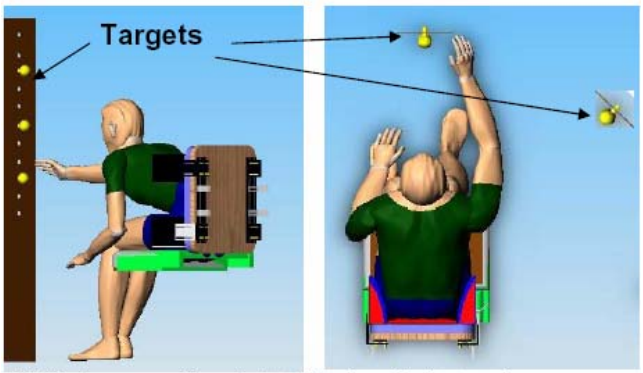
Fig. 1. Evaluating wheelchair user's reaching performance during the arm-length and maximum reaching distances. The side view (Left) and top view (right) are shown here. The targets are shown for Shoulder Height (SH) and 20% above the SH for both reaching to the front and reaching 45˚ laterally.



(A) Reaching to an arm-length distance. Left: Side view, Right: top view



(B) Maximum reaching. Left: Side view, Right: top view

Alternative text for Fig. 1.

Fig. 1. This table shows how the participant reaches for targets at the arm-length distance and maximum reaching distance, shoulder heights of 100% and 120%. Also shown is the reaching directions of straight ahead 0° and 45° laterally.

Table 1: Changes in the lower arm translation during the maximum reaching distance when the sitting posture was changed from Normal to WO-BPS. The results are given for Shoulder Height (SH), 20% above the SH and 20% below the SH for both reaching to the front and reaching 45˚ laterally. A positive value indicates an increase in the lower arm translation.

Lower arm translation	WO-BPS-Normal
Front	
SH	**28.97±170.01**
P	**>0.05**
20% above SH	**-10.44±148.05**
P	**>0.05**
20% below SH	**184.75±196.90**
P	**0.008**
45˚ laterally	
SH	**16.86±248.53**
P	**>0.05**
20% above SH	**-186.73±946.11**
P	**>0.05**
20% below SH	**-616.08±1117.84**
P	**>0.05**

Alternative text for Table 1:

Table 1: This table shows the changes in the lower arm translation during the maximum reaching distance when the sitting posture was changed from Normal to WO-BPS. The results are given for Shoulder Height (SH) and 20% above the SH for both reaching to the front and reaching 45˚ laterally.

Table 2: Changes in the muscle activity (Normalized muscle activity %) during the maximum reaching distance when the sitting posture was changed from Normal to WO-BPS. The results are given for Shoulder Height (SH) and 20% above the SH for both reaching to the front and reaching 45˚ laterally.

Muscles activity (%)	Triceps	Biceps	Ant Del	Upper Trapz	Inf	Ser Ant	SCM	Pect Major
Front								
SH	-3.4±24.6	2.9±19.0	8.3±42.9	-6.9±27.7	-7.6±32.5	-30.4±106.6	6.4±42.4	-4.3±47.3
P	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05
20% above SH	551.1±1890.6	-16.1±33.0	-14.2±47.3	-16.5±59.3	9.6±65.4	10.1±67.3	-10.5±34.0	8.6±27.4
P	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05
45˚ laterally								
SH	-4.8±56.4	-6.0±19.0	-0.4±45.1	4.3±40.4	7.8±35.6	53.8±203.56	3.7±36.2	10.4±14.8
P	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05	**0.034**
20% above SH	-24.1±98.3	-15.0±45.5	-4.6±54.0	10.3±34.1	5.1±44.5	-74.5±177.4	27.8±45.3	21.0±61.5
P	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05

Alternative text for Table 2.

Table 2: This table displays the changes in the muscle activity (Normalized muscle activity %) during the maximum reaching distance when the sitting posture was changed from Normal to WO-BPS. The results are given for Shoulder Height (SH) and 20% above the SH for both reaching to the front and reaching 45˚ laterally.