

6-2016

# Effects of Adjustments to Wheelchair Seat to Back Support Angle on Head, Neck, and Shoulder Postures

Afnan M. Alkhateeb

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LOMA LINDA UNIVERSITY  
School of Allied Health Professions  
in conjunction with the  
Faculty of Graduate Studies

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Effects of Adjustments to Wheelchair Seat to Back Support Angle  
on Head, Neck, and Shoulder Postures

by

Afnan M. Alkhateeb

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A Dissertation submitted in partial satisfaction of  
the requirements for the degree  
Doctor of Science in Physical Therapy

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June 2016

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Each person whose signature appears below certifies that this dissertation in his/her opinion is adequate, in scope and quality, as a dissertation for the degree Doctor of Science.

\_\_\_\_\_, Chairperson  
Bonnie J. Forrester, Associate Professor of Physical Therapy

\_\_\_\_\_  
Noha S. Daher, Associate Professor of Epidemiology and Biostatistics

\_\_\_\_\_  
Bradford D. Martin, Professor of Physical Therapy

## ACKNOWLEDGEMENTS

I would like to thank Loma Linda University, especially School of Allied Health Professions, for offering me the opportunity to pursue my doctoral degree in physical therapy.

I would like to extend my sincere gratitude to my committee: Dr. Bonnie Forrester, Dr. Noha Daher, and Dr. Bradford D. Martin. Dr. Bonnie Forrester for providing me with feedback for this project, as well as knowledge, guidance, and support. Also, I thank her for the time and effort she put while reviewing the content of my study. She believed in me and encouraged me to achieve and complete my project. I would like to express my deepest thanks and gratitude to Dr. Noha Daher for being such a huge support through my education years in Loma Linda University. She was supportive all the time as much as needed and more during my journey. She offered me a big support and time during statistical analysis for my research project. I am so glad and lucky to be one of her students, she is such a great teacher, friend, big sister, and mom. Also, I would like to give special thanks to Dr. Bradford D. Martin for his support and help as much as I need for revising, editing, and direction while I was writing my dissertation and submitting papers for publication.

I would like to gratefully thank Dr. Everett Lohman, Program Director for the Post-professional Physical Therapy Programs, for all his help, support, and guidance thorough all my education years here in Loma Lind University. Also, I would like to thank Dr. Gurinder Bains for his help with the IRB papers. Moreover, I would like to thank the program coordinator, Sondra Caposio, who was so humble, helpful, and kind all the time when resolving administrative issues.

Many special thanks for my lovely parents Mohammed Nasser and Eman for everything they have done for me. I am so blessed to have parents like them. Also, many thanks for my brothers Ameen, Muhannad, Abdulaziz, and Yousif, and my sisters Haneen and Dalal.

Many and huge special thanks and gratitude for my lovely husband Sultan Bakhuraybah and my two children Talah and Anas. Without their incredible support and encouragement, I wouldn't be here today. Many thanks for their patience, love, and support to me during this journey, and I am sorry for being busy many times and not spending enough time with them. Words are not enough to express my gratitude and love for them.

I would not forget to extend my thanks to my country Saudi Arabia for offering me this scholarship through King Abdulaziz University.

“All the praises and thanks be to Allah, Who has guided us to this, and never could we have found guidance, were it not that Allah had guided us!”

(Al-A'raf; 43 Chapter No.7, Holy Qur'an).

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## ABBREVIATIONS

CP	Cerebral Palsy
CE	Coach's Eye application
SHA	Sagittal Head Angle
CVA	Cervical Angle
SA	Shoulder Angle
CROM	Cervical Range of Motion
COM	Center of Mass
BOS	Base of Support

## ABSTRACT OF THE DISSERTATION

Effects of Adjustments to Wheelchair Seat to Back Support Angle

on Head, Neck, and Shoulder Postures

by

Afnan ALkhateeb

Doctor of Science, Graduate Program in Physical Therapy

Loma Linda University, June 2016

Dr. Bonnie J. Forrester, Chairperson

**Background:** People spend a long time in the sitting position may have poor alignment that leads to neck and back pain. A wheelchair represents mobility for people with cerebral palsy, who are unable to walk. They spend long periods of time sitting in their wheelchair. Opining the seat to back support angle of the wheelchair enable realignment body segments and improves posture.

**Objective:** 1) assessed the validity/reliability of Coach's Eye (CE) smart device application, 2) examined the effect of seat to back support angle adjustments on head, neck, and shoulder posture in the sitting position, and 3) compared changes in cervical rotation at each seat to back support angle.

**Methods:** Thirty-four subjects between the ages of 18 and 45 years abled subjects and subjects with cerebral palsy. All subjects sat in a research wheelchair with seat to back support angle at (90°, 100°, and 110°). Photographs were taken and analyzed by ImageJ and cache's Eye (CE) software. Three body posture angles were used: sagittal head angle (SHA), cervical angle (CVA), and shoulder angle (SA).

**Results:** There were highly significant differences on abled subjects for CVA and SA ( $p < 0.001$ ) among the three seat to back support angles. CE had high validity for all angles

( $r = 0.99, 0.98, 0.99$  respectively,  $p < 0.001$ ). Inter-rater reliability for SHA, CVA, and SA among the three seat to back support angles was high (ICC ranged from 0.95 to 0.99). There were highly significant differences on abled subjects for CVA and SA ( $p < 0.001$ ). There were highly significant differences on subjects with cerebral palsy for SHA and CVA ( $p < 0.001$ ) among the three seat to back support angles.

**Conclusion:** Head (CVA) and shoulder (SA) alignment was closest to neutral posture for abled subjects with seat to back support angles set at  $110^\circ$  and  $90^\circ$ , respectively. Head (SHA) and (CVA) alignment was closest to neutral posture for subjects with CP with seat to back support angles set at  $110^\circ$ .

**Keywords:** seat to back support angle of wheelchair, sitting posture, cerebral palsy sagittal head angle, cervical angle, shoulder angle, ImagJ, Coach's Eye, CROM.

## CHAPTER ONE

### INTRODUCTION

The resting posture for humans is sitting, which diminishes energy consumption during daily activities (Strobl, 2013). The term posture describes as the interrelationship of various body segments to each other's (Chung, Evans, Lee, Lee, Rabbani, Roxborough, & Harris, 2008). Zollars (2010) describes neutral posture as "the posture in which the person's body is well-aligned, stable, and balanced;" with well-aligned posture described as: pelvis upright and level or slightly forward, upright trunk with natural curves of the spine, hips and legs slightly abducted, knees and ankles flexed usually at 90°, feet supported by footrests or on the floor, head upright and in midline of the body, and shoulders and arms relaxed and free to move (Zollars, 2010). Erect posture in humans reduces musculoskeletal stress (Ruivo, Pezarat-Correia, & Carita, 2015). Poor posture alignment allows antigravity forces to act on the joints and causes extra effort to be required of muscles and joints, which leads to tension in muscles, impeded joint motion, and pain (Ruivo, Pezarat-Correia, & Carita, 2014).

Neutral posture is affected by the interaction between the neuromuscular system and the biomechanical elements in order to be erect against gravitational forces. (Claus, Hides, Moseley, & Hodges, 2009). Neutral sitting balance posture includes elements that allows a balance between stability and mobility, which allows the completion daily life activities and does not cause harm to body structures (Hendrie, 2009). Stability of posture has been defined as capability of preserving the center of mass (COM) over the base of

support (BOS) to prevent imbalance in posture or movement and achievement of optimal position or motion (Westcott, Lowes, & Richardson, 1997).

Inappropriate sitting posture impacts control of head position, which is necessary for orientation, communication, functional performances in daily life at home or in the community (McNamara & Casey, 2007). Optimal head position has a positive effect on heart rate, breathing, swallowing, and vision, and plays a role in social communication, interaction, and learning (Fitzsimmons, 2014). Good sitting posture realize on control and position of the head. One of the most common head alignment issues regarding inappropriate sitting position is forward head posture, which transfers the cervical spine into a forward orientation. Moreover, forward head posture includes integration of extension in the upper cervical region, flexion of the lower cervical region, and protraction of the shoulders (Nam, Son, Kwon, & Lee, 2013). There are many physical complications related to forward head posture, such as upper cervical extension (C1-C4), lower cervical flexion (C5-T1), increased upper thoracic kyphosis, scapulae protraction (that develops along with elevation and downward rotation), humeri internal rotation, first and second rib elevation, which all negatively impact appropriate posture (Donald D. Harrison & Harrison, 1999).

There is a strong biomechanical relationship exists between the head and neck, inappropriate forward head posture during sitting is considered a hazard for neck pain (van Niekerk, Louw, Vaughan, Grimmer-Somers, & Schreve, 2008),(Horton, 2010). Forward head posture is described as anterior translation of the head in the sagittal plane which leads to the head situated in front of the trunk a long with an extra upper cervical extension (Silva, Punt, Sharples, Vilas-Boas, & Johnson, 2009). All can cause pain

resulting from change in stretch and strength of the connective tissue of the neck by requiring additional stretching of anterior components and compensation with shortening of the posterior components (Silva, Punt, Sharples, Vilas-Boas, & Johnson, 2009). The head position for individuals with cerebral palsy (CP) have to be close to neutral head alignment, in order to orient their eyes to the horizontal level and improve visual field (Fitzsimmons, 2014).

People with CP spend much of daily life in sitting in order to have wide surface support rather than the small one needed during standing (Liao, Yang, Hsu, Chan, & Wei, 2003), due to motor impairments which lead to difficulties with preserving appropriate antigravity postural control (Chung, Evans, Lee, Lee, Rabbani, Roxborough, & Harris, 2008). Researchers have found that appropriate alignment and stability during sitting lead to enhances function (Liao, Yang, Hsu, Chan, & Wei, 2003). Individuals with CP display various seating issues, and one of their complications is the inability to control sitting posture. (Fife, Roxborough, Armstrong, Harris, Gregson, & Field, 1991). People with severe CP are unable to sustain erect sitting posture due to loss of ability to stabilize the postural muscles of their neck and trunk (Cherng, Lin, Ju, & Ho, 2009). Asymmetrical posture can lead to an increase in musculoskeletal abnormalities in individuals with CP, but recent discoveries and precautionary intervention can minimize some serious complications (Rodby-Bousquet, Agustsson, Jonsdottir, Czuba, Johansson, & Hagglund, 2014). Clinically, adult wheelchair users usually move their pelvis forward into sacral sitting, which causes increased thoracic kyphosis, compensatory with increased upper cervical extension, shoulder protraction, and loss of lumber lordosis (Li, Chen, Chang, & Tsai, 2014). Sitting upright is hard to maintain because it requires ongoing activation of



the erector spine muscles. Consequently, to rest from exaggerated muscle activity, slumped posture occurs along with sacral sitting, posterior pelvic rotation, thoracic kyphosis, and cervical lordosis, along with loss of lumbar lordosis (Pynt, Higgs, & Mackey, 2001). People usually stay away from fixed postures by changing position frequently (Donald D. Harrison & Harrison, 1999).

Many studies mention the 90°-90°-90° sitting position (which refers to degrees of flexion at hips, knees, and ankles) as a neutral upright seating posture (Neville, 2005). Sitting at a right angle is difficult to maintain for a long time, so wheelchair users resort to move the pelvis forward to counter the discomfort and fatigue, due to excessive muscle activity. Moreover, a 90 degree seat to back support angle will encourage sacral sitting which the wheelchair user will often assume with increase thoracic kyphosis, increase cervical lordosis, and loss of lumbar lordosis (Neville, 2005).

A common intervention for providing sitting posture control for individuals with CP is the use of assistive seating systems to enhance sitting alignment (Chung, Evans, Lee, Lee, Rabbani, Roxborough, & Harris, 2008). Adaptive seating devices are any object, material, instrument, or technique applied to control, or develop the functional capabilities of the individual with CP (Ryan, Campbell, Rigby, Fishbein-Germon, Hubley, & Chan, 2009). Application of adaptive sitting posture as a restorative tool for mobility promotes posture control, reduces musculoskeletal contractures, minimizes bone deformities, decreases pressure sores, and improves functional ability (Fife, Roxborough, Armstrong, Harris, Gregson, & Field, 1991).

Research studied using adaptive seating as an intervention for individuals with CP, including modifications to the seat to back support angle of the wheelchair (Chung,

Evans, Lee, Lee, Rabbani, Roxborough, & Harris, 2008). There is disagreement about the appropriate orientation of the seat to back support angle, but there is agreement in how tilt or recline features influence postural control of individuals with CP (McNamara & Casey, 2007). People with CP have varying impairments that affect their postural stability, which means the design of the wheelchair must be unique to each individual (Chung, Evans, Lee, Lee, Rabbani, Roxborough, & Harris, 2008; Desroches, Aissaoui, & Bourbonnais, 2006).

Wheelchair seat to back support angle modification can improve postural alignment of the body by changing orientation of these body parts to minimize the pull of gravity on the head (Dicianno, Arva, Lieberman, Schmeler, Souza, Phillips, Lange, Cooper, Davis, & Betz, 2009). Many biomechanical studies recommend that the chair seat to back support angle should have an inclination of 110 degrees to minimize forward head and realign body posture to be close to neutral posture (Harrison, Harrison, Croft, Harrison, & Troyanovich, 1999). Opening the angle of the seat to back support will allow the head and trunk to be in balance in relation to the pull of gravity (Neville, 2005). Horton (2010) reported a significant difference in head and neck postures when office chair seat to back support angles were opened to 100 and 110 degrees.

One of the primary goals of physical therapists is correction poor alignment in their patients, usually undertaken by subjective visual investigation (Ferreira, Duarte, Maldonado, Burke, & Marques, 2010). Visual analysis of photographs or elementary apparatus such as gravity lines, body landmarks, or tapes are widely used to measure posture because no definitive method for posture measurement exists (McEvoy & Grimmer, 2005). Photographs provide valid and reliable indicators of the position of the

underlying spine in sitting, when compared to radiographs using the LODOX (van Niekerk, Louw, Vaughan, Grimmer-Somers, & Schreve, 2008).

According to the United States Census Bureau's Survey, in 2002 there were 2.7 million wheelchair users and this number was predestined to increase to 3.86 million by 2009 (Nelson, Groer, Palacios, Mitchell, Sabharwal, Kirby, Gavin-Dreschnack, & Powell-Cope, 2010). Wheelchair users sit in their wheelchairs for many hours per day in order to be mobile (Rispin & Wee, 2014). Choosing an appropriate seating device can enhance sitting posture and daily function, because seating contributes to stabilizing trunk musculature allowing the head and neck to position appropriately (Hastings, Fanucchi, & Burns, 2003).

The objectives of this study were to: 1) assessed the validity/reliability of Coach's Eye (CE) smart device application, 2) examined the effect of seat to back support angle adjustments on head, neck, and shoulder posture in the sitting position for abled subjects and subjects with cerebral palsy, and 3) compared changes in cervical rotation at each seat to back support angle.

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**CHAPTER TWO**  
**VALIDITY AND RELIABILITY OF WHEELCHAIR SITTING POSTURE**  
**MEASURES USING COACH'S EYE IN ABLED SUBJECTS**

Afnan M. Alkhateeb, PT, MPT, DSc<sup>1,2</sup>, Bonnie J. Forrester, PT, MS, DSC, PCS<sup>1</sup>, Noha S. Daher, MSPH, DrPH<sup>3</sup>, Bradford D. Martin PT, PhD<sup>1</sup>, Asma A. Alonazi, PT, MPT<sup>1</sup>

*<sup>1</sup>Department of Physical Therapy, School of Allied Health Professions*

*Loma Linda University, Loma Linda, California, USA*

*<sup>2</sup>Physical Therapy Department, Faculty of Applied Medical Sciences, King Abdulaziz University, Jeddah, Kingdom of Saudi Arabia*

*<sup>3</sup>Department of Allied Health Studies, School of Allied Health Professions, Loma Linda University, Loma Linda, California, USA*

Department of Physical Therapy, School of Allied Health Professions  
Loma Linda University, Loma Linda, California, USA



## Abstract

People in wheelchairs spend a long time in the sitting position and often incur alignment problems, resulting in neck and back pain. Finding an appropriate sitting posture and using a simple and valid technique to measure the sitting posture is needed. This study: 1) assessed the validity/reliability of Coach's Eye (CE) smart device application, 2) examined the effect of seat to back support angle adjustments on head, neck, and shoulder posture in the sitting position, and 3) compared changes in cervical rotation at each seat to back support angle. Able subjects sat in a wheelchair with back support angles positioned at 90°, 100°, and 110°. Coach's Eye, as well as ImageJ software, was used to analyze three angles; sagittal head angle (SHA), cervical angle (CVA), and shoulder angle (SA). There were highly significant differences for CVA and SA ( $p < 0.001$ ) among the three seat to back support angles. Validity of CE was examined by correlating CE with ImageJ scores. CE had high validity for all angles ( $r = 0.99, 0.98, 0.99$  respectively,  $p < 0.001$ ). Inter-rater reliability for SHA, CVA, and SA was high (ICC ranged from 0.95 to 0.99). Head (CVA) and shoulder (SA) alignment was closest to neutral posture with seat to back support angles set at 110° and 90°, respectively.

**Keywords:** seat to back support angle of wheelchair, sitting posture, sagittal head angle, cervical angle, shoulder angle, ImageJ, Coach's Eye, CROM.

## Introduction

The sitting position is used by various groups of people, such as office workers, drivers, and students to accomplish daily functions such as eating, working, communication, or rest (Strobl, 2013). Wheelchair users sit in their wheelchairs for many hours per day in order to be mobile (Rispin & Wee, 2014). Sitting posture is described as the alignment of body segments in relation to each other at a specific time in space, and neutral posture in sitting is important to reduce musculoskeletal stresses (Ruivo, Pezarat-Correia, & Carita, 2015). Zollars (2010) describes neutral posture as “the posture in which the person’s body is well-aligned, stable, and balanced;” with well-aligned posture described as: pelvis upright and level or slightly forward, upright trunk with natural curves of the spine, hips and legs slightly abducted, knees and ankles flexed usually at 90°, feet supported by footrests or on the floor, head upright and in midline of the body, and shoulders and arms relaxed and free to move (Zollars, 2010). Neutral sitting posture allows for both stability and mobility, in which the body is enabled to accomplish daily life activities, without harm to body structures (Hendrie, 2009).

Neutral sitting posture is affected by the interaction between body segments and gravity (Claus, Hides, Moseley, & Hodges, 2009). A stable neutral posture is able to preserve the body center of mass (COM) over its base of support (BOS) to achieve optimal position and motion (Westcott, Lowes, & Richardson, 1997). Poor postural alignment increases antigravity forces on joints and soft tissue in order to maintain the body center of mass over its base of support, and thus leads to tension in muscles, impeded joint motion, and pain (Ruivo, Pezarat-Correia, & Carita, 2014).

A strong relationship exists between the head and neck during sitting. The position of the head in sitting has an effect on heart rate, breathing, swallowing, vision, as well as social interaction (Fitzsimmons, 2014). Forward head posture is described as anterior translation of the head in the sagittal plane, which leads to the head being positioned in front of the trunk, causing extra upper cervical extension to maintain the visual field (Silva, Punt, Sharples, Vilas-Boas, & Johnson, 2009). Forward head posture, with subsequent cervical extension during sitting, can lead to neck pain due to antigravity forces exerted on the soft tissues of the neck, and results in the stretching of anterior components with compensatory shortening of the posterior components (Silva, Punt, Sharples, Vilas-Boas, & Johnson, 2009). Clinically, adult wheelchair users who sit for long periods of time, develop an increase thoracic kyphosis with subsequent increased upper cervical extension, and shoulder protraction (Li, Chen, Chang, & Tsai, 2014).

For people who sit for long periods of time, posture alignment can be improved with modification to the seat to back support angle of their seating device, which changes the orientation of their body parts to minimize the pull of gravity on the head (Dicianno, Arva, Lieberman, Schmeler, Souza, Phillips, Lange, Cooper, Davis, & Betz, 2009). Many studies mention the 90°-90°-90° sitting position (which refers to degrees of flexion at hips, knees, and ankles) as a neutral upright seating posture (Ham, Aldersea, & Porter, 1998; Neville, 2005). Sitting with the hips at a right angle is difficult to maintain for a long period of time and causes people to change their position to avoid discomfort and fatigue. One positional change is to move their pelvis forward into sacral sitting, which leads to increased thoracic kyphosis, compensatory cervical lordosis, and loss of lumbar lordosis (Neville, 2005). Many biomechanical studies recommend that the chair seat to

back support angle should have an inclination of 110 degrees to minimize forward head posture and to realign the body close to ideal posture (Harrison, Harrison, Croft, Harrison, & Troyanovich, 1999). Opening the angle of the seat to back support will allow the head and trunk to be in balance in relation to the pull of gravity (Neville, 2005). Horton (2010) reported a significant difference in head and neck postures when office chair seat to back support angles were opened to 100 and 110 degrees.

One of the primary goals of physical therapists is correction of poor alignment in their patients, usually undertaken by subjective visual investigation (Ferreira, Duarte, Maldonado, Burke, & Marques, 2010). Visual analysis of photographs utilizing elementary apparatus with gravity lines, body landmarks, or tape measure are widely used to measure posture, because there are no other valid and reliable methods, except for radiograph analysis (McEvoy & Grimmer, 2005). Photographs provide valid and reliable indicators for the position of the underlying spine in sitting when compared to radiographs utilizing LODOX (van Niekerk, Louw, Vaughan, Grimmer-Somers, & Schreve, 2008). Photogrammetry is a method extensively used for assessing postural alignment of individuals in photographs (Ruivo, Pezarat-Correia, & Carita, 2015).

There are many body angles used to evaluate sitting posture, such as sagittal head angle (SHA), cervical angle (CVA), and shoulder angle (SA). Sagittal head angle is reliable for evaluating head position in relation to the neck (Chansirinukor, Wilson, Grimmer, & Dansie, 2001) and is formed by the junction of a horizontal line through the tragus of the ear with a line from tragus to the lateral canthus of the eye (Ruivo, Pezarat-Correia, & Carita, 2014). Cervical angle is formed by the junction of a horizontal line through the C7 spinous process with a line from C7 spinous process to tragus of the ear

(Ruivo, Pezarat-Correia, & Carita, 2014) and is highly reliable for evaluating forward head position (Ruivo, Pezarat-Correia, & Carita, 2014) as one of the most reliable measurements for head posture assessment (Lau, Chiu, & Lam, 2010). SA is formed at the junction of the horizontal line through the head of humerus (midpoint) and a line between the head of humerus (midpoint) and C7 spinous process (Brink, Crous, Louw, Grimmer-Somers, & Schreve, 2009), and is used to measure the protraction or retraction position of the shoulder (van Niekerk, Louw, Vaughan, Grimmer-Somers, & Schreve, 2008) (Ruivo, Pezarat-Correia, & Carita, 2014).

The purpose of this study was to establish a standard using abled subjects before applying these techniques with people who have cerebral palsy by: 1) assessing the criterion validity/inter-rater reliability of Coach's Eye (CE) smart device application that was employed to measure the posture angle in abled subjects, 2) examining the effect of seat to back support angle adjustment on head (SHA), neck angle (CVA), and shoulder angle (SA), and 3) comparing the changes in cervical rotation range of motion among the three seat to back support angles (i.e. 90°, 100°, and 110°).

## **Methods**

### ***Study Design***

A cross-sectional study was conducted on abled subjects without disability or abnormal deformities. All subjects were screened for inclusion and exclusion criteria at baseline.

### ***Subjects***

This study was approved by the Institutional Review Board (IRB) at Loma Linda University (LLU) and conducted at Nichol Hall room A640/A620 at Loma Linda University at the School of Allied Health Professions (SAHP), Department of Physical Therapy. The participation of all subjects was voluntary, and written informed consent was obtained from subjects before commencing the study.

Twenty-five subjects were recruited from San Bernardino and Riverside Counties by word of mouth or by phone, who were male or female between the ages of 18 and 45 old. Subjects were pre-screened using a self-report health questionnaire. Subjects were excluded if they had history of head, neck, shoulder, low back injury, neurologic disease, musculoskeletal diseases (such as a history of shoulder surgery, or current shoulder pain), or any spinal abnormalities (such as displayed functional or structural scoliosis, or had excessive thoracic kyphosis).

Subjects were asked to wear suitable clothing, such as a tank top that will allow their neck and shoulders to be exposed for the photographs and to tie up long hair as needed.

### ***Equipment***

We used Invacare's Solara tilt and recline manual wheelchair, with Freedom Designs' linear back and seat (10-cm thickness of foam covered with Dartex), a pelvic strap attached at a 45° angle to the seat, and 90° foot hangers and footplates attached. This wheelchair could be positioned at the three seat to back support angles tested in this study. An angle finder tool, purchased at local hardware store, was attached to the back

support of the wheelchair. Also, a smart phone (iPhone 6 plus), tripod, and cellphone adaptor were used to take photographs.

Two programs on two different devices were used to analyze the photographs. First, ImageJ, a public domain, Java-based image-processing program, developed by the National Institutes of Health. Second, Coach's Eye (CE), a performance-enhancing smart device application with an angle tool, was used to evaluate movement and posture.

Cervical rotation was measured using a cervical range of motion (CROM) device, which is a valid and reliable device to use for persons with or without neck pain (Audette, Dumas, Cote, & De Serres, 2010; Fletcher & Bandy, 2008).

### *Procedures*

The wheelchair was positioned sideways in front of a white sheet suspended from the ceiling. A rectangle was taped out on the ground using 1.88 inch-wide (4.78 centimeter) duct tape to outline the same dimensions as the wheelchair's ground footprint, in order to insure consistent placement of the front and rear wheels throughout the study. The angle finder was secured by Velcro to an L-bracket attached to the top left edge of the back support. The front and back of the seat was measured, using a steel tape measure to insure it was horizontal to the ground. We mounted a smart phone (iPhone 6 plus) on a tripod using a cellphone adaptor, setting the tripod so that the camera lens of the phone was 47 inches (1.2 meter) from and level to the ground, at 2 meters lateral to the midpoint of the wheelchair on its left side. The midpoint was determined using the left linear tape mark of the rectangle on the ground. This positioning allowed for head and shoulder to be fully captured in each photograph taken.

Subjects sat in the wheelchair positioned at the 90° seat to back support angle, with their buttocks all the way back to the rear, touching the lower portion of the back support. This position was secured by firmly tightening the pelvic strap. Subjects were asked to place their feet on the footplates. A 6-foot (1.83 meter) tall mirror, mounted on wheels was placed 1 meter in front of the subjects. White reflective markers (Foam Mounting Squares), 1 cm square, were placed on 3 landmarks; tragus of ear, C7 spinous process, and head of the humerus (midpoint). The CROM device was placed on the subjects' head. Subjects were asked to sit with their thoracic spine contacting the back support, in a comfortable upright position with arms resting on the wheelchair armrest or on their thigh, whichever was most comfortable.

The camera function of the iPhone 6 plus was turned on. Subjects were asked to take a deep breath and exhale to facilitate relaxation. Then they were asked to look to the ceiling, then look to the ground, and finally look into their own eyes in the mirror positioned in front of them, in order to reproduce the Natural Headrest Position (NHP) as described by (Weber, 2012). Subjects were asked to stay in position for the 3 seconds it took to take a photograph and short video.

To measure cervical rotation, the subjects were asked to rotate first to the right, go back to middle, then rotate to the left, while 2 researchers read the rotation degrees off of the device. The three tests were carried out sequentially as stated above. This sequence was repeated two more time and then the average of these three readings was recorded for analysis.

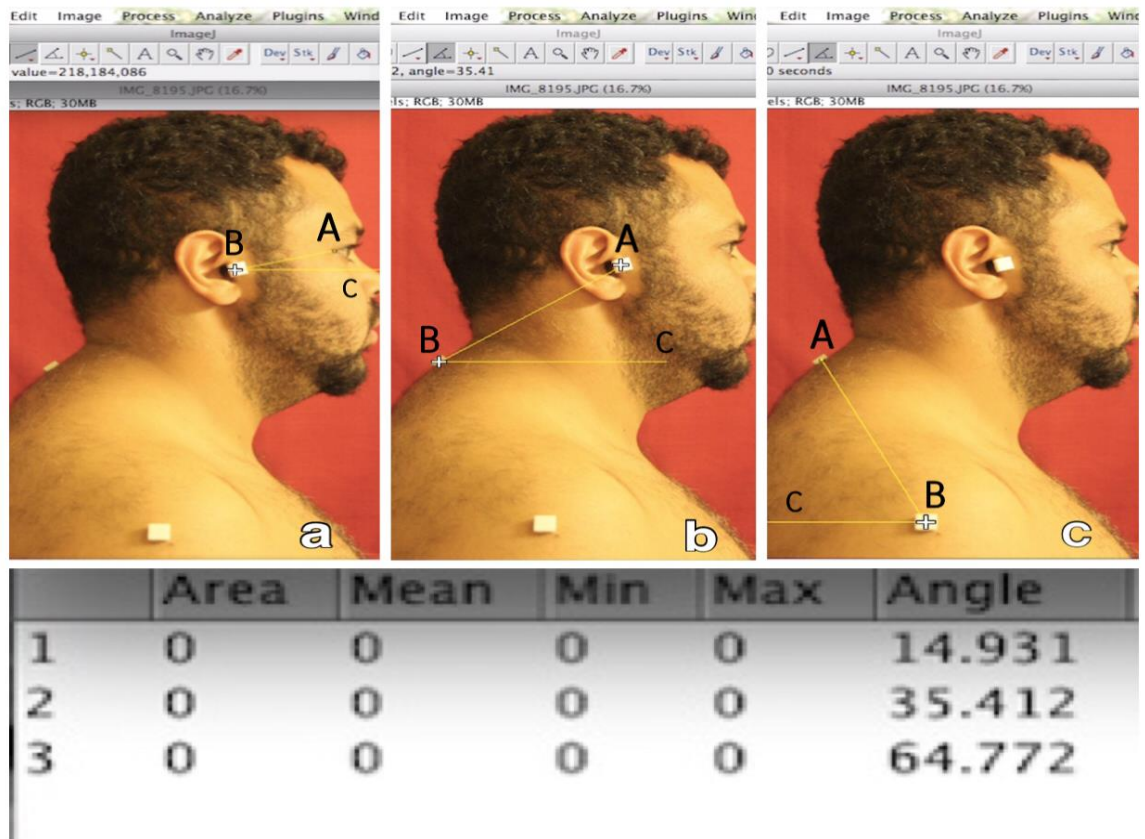
The back support was reclined to 100°, as verified by the angle finder, and the sequential procedure was repeated as stated above, while the buttocks continued to be



secured by the pelvic strap and did not move forward. The back support was reclined to 110° and this procedural sequence was repeated one more time.

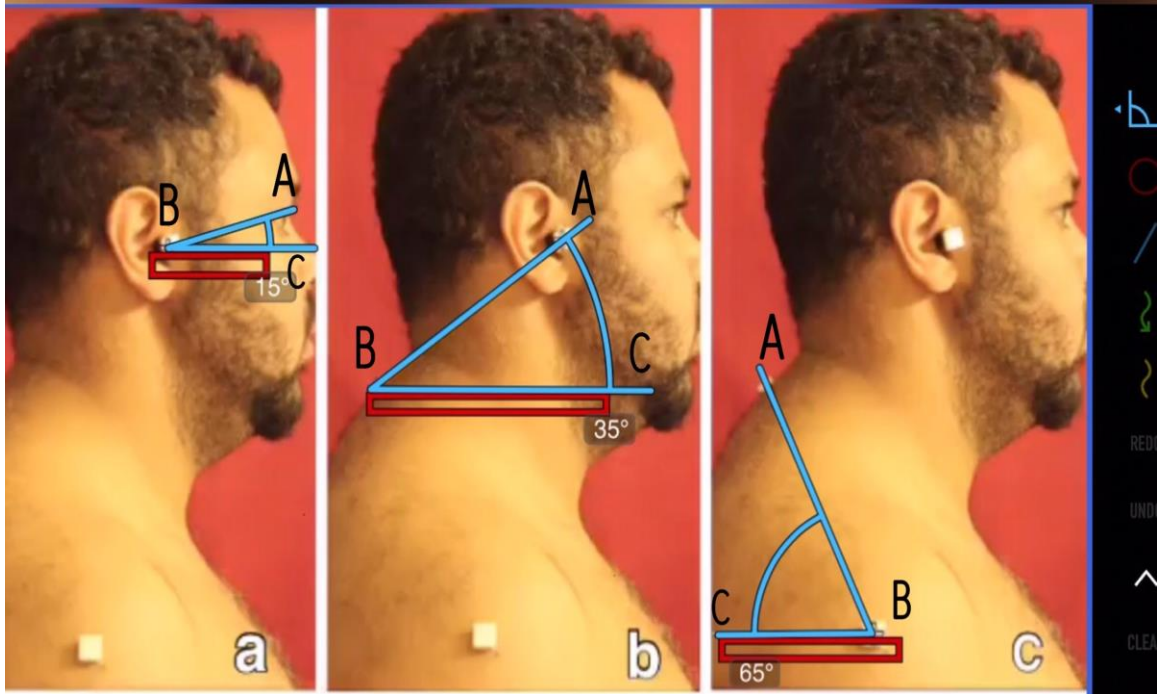
The CROM, reflective markers, and pelvic strap were removed from the subjects, and they then exited the wheelchair with their participation complete.

In terms of ImageJ analysis, photographs were downloaded to a computer that had the ImageJ program. Each photo was dragged to the ImageJ software, and the angle option was selected. Measurement of each angle was obtained by clicking at point A (canthus of the eye for SHA, tragus of the ear for CVA, and C7 spinous process for SA). Next, a line was drawn from point A to point B (tragus of the ear for SHA, C7 spinous process for CVA, and head of the humerus (midpoint) for SA). Finally, a line was drawn from point B to point C (horizontal line anteriorly for SHA and CVA and horizontal line posteriorly for SA) (Figure 1).



**Figure 1.** Measuring the three body angles: a) sagittal head angle (SHA); b) cervical angle (CVA), and c) shoulder angle (SA) by using ImageJ.

Coach's' Eye photographic analysis was done using the following three steps: 1) draw a rectangle parallel to the horizontal line of each body angle (parallel to the line connecting points B and C) to make sure that the horizontal line of each angle is straight and horizontal. Next, 2) draw the actual horizontal line of the measured angle immediately above the rectangle connecting point B (tragus of the ear for SHA, C7 spinous process for CVA, and head of the humerus, midpoint) to point C (horizontal line anteriorly for SHA and CVA, horizontal line posteriorly for SA). Finally, 3) draw the other line of the angle connecting point B to point A (canthus of the eye for SHA, tragus of the ear for CVA, C7 spinous process for SA) (Figure 2).



**Figure 2.** Measuring the three body angles: a) sagittal head angle (SHA), b) cervical angle (CVA), and c) shoulder angle (SA) by using Coach's Eye application.

Two physical therapists participated as raters. They separately performed all body angle measurements on both programs and recorded the degrees (to laptop computer and smart device). The readings were taken from both programs (ImageJ and Coach's Eye) for the three body posture angles (SHA, CVA, SA) at three back support position of wheelchair. Each rater followed the same steps mentioned above and the procedures were repeated for each program. Comparisons of the angle measurements were used to determine inter-rater reliability.

### *Data Analysis*

Data was analyzed using the Statistical Package for the Social Sciences (SPSS) version 23.0. The general characteristics of the subjects were summarized using means and standard deviations for quantitative variables, and frequencies and relative frequencies for categorical variables. The normality of the variables was examined using Kolmogorov-Smirnov test. The criterion validity of the measures using CE program was evaluated by correlating the scores from CE for all seat to back support angles with the scores from the ImageJ using Pearson's correlation. The inter-rater reliability of the all the measurements taken using the two different programs tests was analyzed using intraclass correlation coefficients (ICC) and corresponding 95% confidence intervals (CIs). For each of the ImageJ and CE programs, one way repeated measures analysis of variance (ANOVA) was used to assess changes in the postures of sagittal head angle (SHA), cervical angle (CVA), and shoulder angle (SA) angles at 90°, 100° and 110° seat to back support angles of wheelchair. Post hoc comparisons were conducted using the Bonferroni test. To examine changes in right and left cervical rotation range of motion

among the three backseat wheelchair angles, the Friedman test was used. The level of significance was set at  $p < 0.05$ .

## Results

Twenty-five subjects, mean age  $26.7 \pm 5.3$  years participated in the study. Sixty eight percent of the subjects were females ( $n=17$ ). The distribution of the outcome variables was approximately normal ( $p > 0.05$ ).

For abled subjects in sitting position, the criterion validity of the measurements of the three body angles by CE was established using the ImageJ software as the gold standard. Results showed that these measurements are highly valid. The correlation coefficients between the sagittal head angle among the three seat to back support angles of wheelchair (90, 100 and 110 degrees) using both the CE and ImageJ software were  $r = 0.99, 0.98, \text{ and } 0.99$  respectively,  $p < 0.001$ . Similarly, for the cervical angle, the correlation coefficients were  $0.999, 0.999, \text{ and } 1.0$ ,  $p < 0.001$ . For the shoulder angle, there was a perfect correlation between the measurements using both programs among the three seat to back support angles of wheelchair ( $r = 1.0, p < 0.001$ ).

Using the Coach's Eye, the inter-rater reliability of the photographic measures of sagittal head, cervical, and shoulder angles among the three seat to back support angles of wheelchair (90, 100 and 110 degrees) was high (ICC = 0.95, 95% CI: 0.91, 0.98), (ICC = 0.99, 95% CI: 0.98, 0.99), and (ICC = 0.99, 95% CI: 0.98, 0.99), respectively.

Using ImageJ, there was no significant difference in mean sagittal head angle among the different seat to back support angles of wheelchair (90, 100 and 110 degrees) (mean  $\pm$  standard error (SE);  $20.4 \pm 0.9$  vs.  $20.0 \pm 1.0$  vs.  $20.5 \pm 0.9$  respectively,  $p =$

0.67). However, there was a highly significant difference in mean cervical angle among the different seat to back support angles of wheelchair ( $p < 0.001$ ). Results of the post hoc comparisons using the Bonferroni test showed that there was a highly significant difference in mean cervical angle between 90 and 100 degrees (mean  $\pm$  SE;  $48.1 \pm 1.4$  vs.  $50.4 \pm 1.3$ ,  $p < 0.001$ ), between 90 and 110 degrees (mean  $\pm$  SE;  $48.1 \pm 1.4$  vs.  $51.9 \pm 1.4$ ,  $p < 0.001$ ), and a borderline significant difference between 100 and 110 degrees (mean  $\pm$  SE;  $50.4 \pm 1.3$  vs.  $51.9 \pm 1.4$ ,  $p = 0.05$ ). Also, there was a highly significant difference in mean shoulder angle among the different seat to back support angles of wheelchair ( $p < 0.001$ ). Results of the post hoc comparisons using the Bonferroni test showed that there was a highly significant difference in mean shoulder angle between 90 and 100 degrees (mean  $\pm$  SE;  $39.2 \pm 2.0$  vs.  $36.4 \pm 2.0$ ,  $p = 0.001$ ), between 90 and 110 degrees (mean  $\pm$  SE;  $39.2 \pm 2.0$  vs.  $34.5 \pm 2.1$ ,  $p < 0.001$ ), and a borderline significant difference between 100 and 110 degrees (mean  $\pm$  SE;  $36.4 \pm 2.0$  vs.  $34.5 \pm 2.1$ ,  $p = 0.056$ ; see Table 1).

Using Coach's Eye, there was no significant difference in mean sagittal head angle among the different seat to back support angles of wheelchair (90, 100 and 110 degrees) (mean  $\pm$  standard error (SE);  $20.4 \pm 0.9$  vs.  $20.0 \pm 0.9$  vs.  $20.4 \pm 0.9$  respectively,  $p = 0.48$ ). However, there was a highly significant difference in mean cervical angle among the different seat to back support angles of wheelchair ( $p < 0.001$ ). Results of the post hoc comparisons using the Bonferroni test showed that there was a highly significant difference in mean cervical angle between 90 and 100 degrees (mean  $\pm$  SE;  $48.2 \pm 1.4$  vs.  $50.3 \pm 1.3$ ,  $p = 0.001$ ), between 90 and 110 degrees (mean  $\pm$  SE;  $48.2 \pm 1.4$  vs.  $51.8 \pm 1.4$ ,  $p < 0.001$ ), and a significant difference between 100 and 110 degrees (mean  $\pm$  SE;

50.3 ± 1.3 vs. 51.8 ± 1.4,  $p = 0.037$ ). Also, there was a highly significant difference in mean shoulder angle among the different seat to back support angles of wheelchair ( $p < 0.001$ ). Results of the post hoc comparisons using the Bonferroni test showed that there was a highly significant difference in mean shoulder angle between 90 and 100 degrees (mean ± SE; 39.3±2.0 vs. 36.3±2.0,  $p = 0.001$ ), between 90 and 110 degrees (mean ± SE; 39.3±2.0 vs. 34.6 ± 2.1,  $p < 0.001$ ), and a borderline significant difference between 100 and 110 degrees (mean ± SE; 36.3±2.0 vs. 34.6±2.1,  $p = 0.065$ ; see Table 2).

The distribution of the changes in the right and left cervical rotation range of motion among the three seat to back support angles of wheelchair (90, 100 and 110 degrees) was not approximately normal. There was no significant difference in the right and left cervical rotation among the different angles ( $p = 0.288$  and  $p = 0.437$ , respectively).



**Table 1.** Mean (SE) of three different body angles by seat to back support angle (degrees) using ImageJ (n =25).

Seat to Back Angle	Body Angle		
	SHA	CVA	SA
90°	20.4 (0.9)	48.1(1.4)	39.2 (2.0) <sup>^</sup>
100°	20.0 (1.0)	50.4 (1.3)*	36.4 (2.0)
110°	20.5 (0.9)	51.9 (1.4)*	34.5 (2.1)
<i>p</i> -value <sup>a</sup>	0.67	<0.001	<0.001

Abbreviations: SE, standard error; SHA = sagittal head angle; CVA = cervical angle; SA = shoulder angle.

\*Significant change from 90°

<sup>^</sup> Significant change from 100° and 110°

<sup>a</sup> *p* - values for the null hypothesis that there is a no difference across the three angles

**Table 2.** Mean (SE) of three different body angles by seat to back support angle (degrees) using Coach's Eye (n =25).

Seat to Back Angle	Body Angle		
	SHA	CVA	SA
90°	20.4 (0.9)	48.2(1.4)	39.3 (2.0) <sup>^</sup>
100°	20.0 (0.9)	50.3 (1.3)*	36.3 (2.0)
110°	20.4 (0.9)	51.8 (1.4)*	34.6 (2.1)
<i>p</i> - value <sup>a</sup>	0.48	<0.001	<0.001

Abbreviations: SE, standard error; SHA = sagittal head angle; CVA = cervical angle; SA = shoulder angle.

\*Significant change from 90°

<sup>^</sup> Significant change from 100° and 110°

<sup>a</sup> *p* - values for the null hypothesis that there is a no difference across the three angles

## **Discussion**

### ***Validity and Inter-Rater Reliability***

Results when using ImageJ program and Coach's Eye smart device application were consistent, which means that the measurements taken when using the CE program are highly valid. Furthermore, the CE application is easy to use, affordable (costs about \$20.00), and photos do not need to be downloaded to a computer. Also, it is an application on a smart device and tablet, which makes the assessment and communication between the therapist and the patients easy and timely. In this study, two physical therapists participated as raters, each performing readings of the angles, using both programs. The results of this study demonstrated that both programs had high inter-rater precision. Based on the above findings, physical therapists are encouraged to use the CE application for evaluation of patients' postures.

### ***Postural Study***

Another aim of this study was to determine that adjustment to the seat to back support angle in a wheelchair would change head, neck, and shoulder posture. Harrison & Harrison (1999) describe ideal posture as a vertical relationship between anatomical structures, which is a perpendicular alignment of the ear, shoulder, and hip in reference to the sagittal plane; also, hips and knees positioned horizontally at the same level. Neutral sitting posture occurs when natural spinal curvatures are maintained where gravitational pull is minimized on the vertebral structures. In sitting, the center of mass (COM) of the head and trunk need to be balanced over the base of support (BOS) (i.e. the pelvis) (Westcott, Lowes, & Richardson, 1997). Forward head posture transfers the head's COM

anterior to the BOS in sitting (Harrison, Harrison, Croft, Harrison, & Troyanovich, 1999). With each inch the head moves anteriorly, 10 pounds of weight is added to the neck, while conversely, if the ear is positioned over the shoulder, the weight of the head is balanced over the spine, without extra load (Cailliet, 1977). Forward head posture leads to more stress on the cervical region with changes to the length and strength of neck muscles (Silva, Punt, Sharples, Vilas-Boas, & Johnson, 2009).

Forward head posture is determined by cervical angle, and when this is less than  $50^\circ$  it correlates with excessive upper cervical extension with or without flexion of the lower cervical region (Silva, Punt, Sharples, Vilas-Boas, & Johnson, 2009) (Ruivo, Pezarat-Correia, & Carita, 2014) (La Touche R, 2011). With forward head there is an increase in upper cervical extension with or without lower cervical flexion (La Touche R, 2011), (McKenzie, 1983). While a smaller CVA demonstrates more forwarded head posture, a larger CVA indicates more neutral head and neck alignment (Cheung Lau, Wing Chiu, & Lam, 2009). In this study, the closest to neutral alignment for head posture (CVA) was with the seat to back support angle set at  $110^\circ$ , and the furthest from neutral alignment was with the seat to back support angle set at  $90^\circ$ . Horton and colleagues (2010) found that there was a significant improvement in head posture (CVA) when the seat to back support angle of an office chair was changed to  $110^\circ$ .

In regard to the relation of the head to the upper cervical spine (i.e. SHA), a smaller SHA indicates increased upper cervical extension, and  $15^\circ$  above horizontal was recommended as a neutral SHA measurement (Ruivo, Pezarat-Correia, & Carita, 2014). We find in this study, no significant difference in sagittal head angle (SHA) among the

three different positions of seat to back support angles. The results indicate there is no preferable position for maintaining head posture close to neutral alignment during sitting.

Shoulder angle (SA) readings for all subjects showed some degree of protraction, in all three positions of this study. Shoulder angle represents the position of the shoulder in relation to neck position (Chansirinukor, Wilson, Grimmer, & Dansie, 2001) and a smaller SA indicates more protracted shoulders, while a 52° or greater is considered a neutral shoulder position (Ruivo, Pezarat-Correia, & Carita, 2014). We found that shoulder protraction was less when the seat to back support angle was set at 90°, while it increased when the seat to back support angle was opened to 100°, and increased again when opened further to 110°. The most upright position in this study was with the seat to back support angle set at 90° and was the angle where shoulder protraction was closest to neutral as described by Ruivo et al., (2014). Bullock et al. (2005) found an increase of forward arm movements while their subjects were sitting in an upright (vertical) position (Bullock, Foster, & Wright, 2005). Kalra et al. (2010) reported that shoulder elevation improved when their subjects were sitting in an upright (vertical) position (Kalra, Seitz, Boardman 3rd, & Michener, 2010).

Contemporary life styles pull the head forward in an attempt to get closer to objects, such as cell phones, computers, video games, and books, which leads to extra weight on the neck and upper back tissues. In order to hold the head forward, continuous isometric contractions of the neck and upper back muscles occurs (Han, Park, Kim, Choi, & Lyu, 2016). Over time, tissues of the neck and trunk may adapt to this position.

Sitting with a 90° seat to back support angle transfers the COM of the head anteriorly. Observationally, able bodied subjects in this study compensated by retracting

their shoulders to bring the COM of the head back toward the BOS. When opening the seat to back support angle, the head posture realigned closer to neutral, which is most likely due to allowing the COM of the head to be balanced over the BOS, with compensatory postural changes no longer be needed.

Another consideration regarding the findings of this study was that the linear back support with shoulder height was in complete contact with the subjects' trunk at 90°. This flat position of the back support did not have modification to accommodate thoracic and lumbar curvatures and required the subjects to maintain a fully upright posture for several minutes. This position is difficult to maintain because it pushes the COM of the head forward of the pelvis, which is the center of their BOS in sitting. Typically, people compensate for this forced posture by moving their trunk and head forward, or by moving their pelvis forward into sacral sitting (Harrison, Harrison, Croft, Harrison, & Troyanovich, 1999).

Based on the results of this study, there is no one seat to back support angle that leads to improved sitting posture when comparing all three body angles (SHA, CVA, and SA) at the same time, for these able-bodied subjects. When choosing a seat to back support angle, one must consider the habitual work and life-sitting postures for each subject. O'Sullivan (2012) reports there is disagreement about the best sitting posture, stating that the most useful sitting posture corresponds with a neutral spine, which minimizes muscular tension (O'Sullivan, O'Sullivan, O'Sullivan, & Dankaerts, 2012).

### ***Cervical Rotation Study***

Regarding the functional dynamic movement assessments at various static postures, there was no significant difference or improvement in cervical rotation range among the three angles of posture. Further research is needed to examine these findings.

### **Limitations**

We did not standardized placement of the subjects forearms, allowing them to choose whether they placed their forearms on their laps or on the armrests of the wheelchair. This may affect the shoulder angle (SA) from one subject to the other. However, each subject remained in the same starting position of the upper extremities through all three seat to back support angles.

### **Conclusion**

Based on the results of this study, Coach's Eye is a valid and reliable program to measure body posture angles. In addition, sagittal head angle (SHA) is the same in all three positions. There is less forward head (CVA) with the seat to back support angle set at 110°, and less protraction shoulder (SA) with the seat to back support angle set at 90°. Finally, there is no specific seat to back support angle that leads to improved posture when considering all three body angles for the able-bodied subjects.

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## CHAPTER THREE

### EFFECTS OF ADJUSTMENTS TO WHEELCHAIR SEAT TO BACK SUPPORT ANGLE ON HEAD, NECK, AND SHOULDER POSTURES IN SUBJECTS WITH CEREBRAL PALSY

Afnan M. Alkhateeb, PT, MPT, DSc<sup>1,2</sup>, Bonnie J. Forrester, PT, MS, DSC, PCS<sup>1</sup>, Noha  
S. Daher, MSPH, DrPH<sup>3</sup>, Bradford D. Martin PT, PhD<sup>1</sup>

<sup>1</sup>*Department of Physical Therapy, School of Allied Health Professions  
Loma Linda University, Loma Linda, California, USA*

<sup>2</sup>*Physical Therapy Department, Faculty of Applied Medical Sciences, King Abdulaziz  
University, Jeddah, Kingdom of Saudi Arabia*

<sup>3</sup>*Department of Allied Health Studies, School of Allied Health Professions, Loma Linda  
University, Loma Linda, California, USA*

Department of Physical Therapy, School of Allied Health Professions  
Loma Linda University, Loma Linda, California, USA

## Abstract

A wheelchair represents mobility for people with cerebral palsy, who are unable to walk. They spend long periods of time sitting in their wheelchair, which can affect their head and neck alignment. Opening the seat to back support angle of the wheelchair can realignment body segments and improves posture. The objective of this study was to examine the effect of seat to back support angle adjustments on head, neck, and shoulder posture in people with cerebral palsy, using three seat to back support angles (90°, 100°, 110°). Subjects with cerebral palsy who use a wheelchair for mobility sat in a research wheelchair. Coach's Eye was used to analyze three angles; sagittal head angle (SHA), cervical angle (CVA), and shoulder angle (SA) from photographs. There were significant differences in mean SHA and CVA among the different seat to back support angles. However, there was no significant difference in mean SA ( $p < 0.001$ ). Head (SHA) and (CVA) alignment was closest to neutral posture with seat to back support angles set at 110°.

**Keywords:** seat to back support angle of wheelchair, sitting posture, cerebral palsy, sagittal head angle, cervical angle, shoulder angle, ImagJ, Coach's Eye, CROM.

## Introduction

Cerebral palsy (CP) is a non-progressive condition, which displays many neurological problems. It is caused by damage or lesion to the brain of the fetus, infant, or young child and can develop during pregnancy, at birth, or post partum (Sandström, 2009). CP is comprised of different neuromuscular and musculoskeletal complications involving spasticity, dystonia, contractures, atypical bone growth, poor balance, lack of specific motor control, and bony deformities (Liao, Yang, Hsu, Chan, & Wei, 2003) (Papavasiliou, 2009). Conditions vary from mild to severe and can involve muscle tone abnormalities, irregular movements of muscles, and abnormal permanence of primitive reflexes (McNamara & Casey, 2007).

People with CP experience trunk and extremity motor impairment, which can lead to difficulties with preserving appropriate antigravity postural control (Chung, Evans, Lee, Lee, Rabbani, Roxborough, & Harris, 2008). One of the serious complications of CP is the inability to control sitting posture. People with CP spend much of daily life in sitting in order to have wide surface support rather than a small one needed during standing (Liao, Yang, Hsu, Chan, & Wei, 2003). Researchers have found that appropriate alignment and stability during sitting can enhance functional execution (Liao, Yang, Hsu, Chan, & Wei, 2003). Individuals with cerebral palsy display various seating issues (Fife, Roxborough, Armstrong, Harris, Gregson, & Field, 1991). People with severe CP palsy are unable to sustain erect sitting posture due to loss of ability to stabilize the postural muscles of their neck and trunk (Cherng, Lin, Ju, & Ho, 2009). Asymmetrical posture can lead to an increase in musculoskeletal abnormalities in individuals with CP, but recent discoveries and precautionary intervention can minimize some serious complications

(Rodby-Bousquet, Agustsson, Jonsdottir, Czuba, Johansson, & Hagglund, 2014).

A common intervention for providing sitting posture control for individuals with CP is the use of assistive seating systems to enhance sitting alignment (Chung, Evans, Lee, Lee, Rabbani, Roxborough, & Harris, 2008). Adaptive seating devices are any object, material, instrument, or technique applied to control, or develop the functional capabilities of the individual with CP (Ryan, Campbell, Rigby, Fishbein-Germon, Hubley, & Chan, 2009). Application of adaptive sitting posture as a restorative tool for mobility promotes posture control, reduces musculoskeletal contractures, minimizes bone deformities, decreases pressure sores, and improves functional ability (Fife, Roxborough, Armstrong, Harris, Gregson, & Field, 1991).

Inappropriate sitting posture impacts control of head position, which is necessary for orientation, communication, functional performances in daily life at home or in the community (McNamara & Casey, 2007). One of the most common head alignment issues regarding inappropriate sitting position is forward head posture, which transfers the cervical spine into a forward orientation. Moreover, forward head posture includes integration of extension in the upper cervical region, flexion of the lower cervical region, and protraction of the shoulders (Nam, Son, Kwon, & Lee, 2013). In order to orient their eyes to the horizontal level and improve visual field for people with CP, their head have to be close to neutral head alignment (Fitzsimmons, 2014). There are many physical complications related to forward head posture, such as upper cervical extension (C1-C4), lower cervical flexion (C5-T1), increased upper thoracic kyphosis, scapulae protraction (that develops along with elevation and downward rotation), humeri internal rotation, first and second rib elevation, which all negatively impact appropriate posture (Donald D.

Harrison & Harrison, 1999). Correcting the position of the head leads to improve breathing, swallowing, heart rate, communication, learning, visual field, and comfort, as well as reduced effect of abnormal reflexes and tone (Fitzsimmons, 2014).

Wheelchair users frequently move their pelvis forward into sacral sitting when sitting for long periods of time, which increases back pain and changes normal spinal curvature (Li, Chen, Chang, & Tsai, 2014). Sitting upright is hard to maintain because it requires ongoing activation of the erector spine muscles. Consequently, to rest from exaggerated muscle activity, they set with forward sitting posture which occurs along with sacral sitting, posterior pelvic rotation, thoracic kyphosis, and cervical lordosis, as well as with loss of lumbar lordosis (Pynt, Higgs, & Mackey, 2001). People usually stay away from fixed postures by changing position frequently (Donald D. Harrison & Harrison, 1999).

Research has supported using adaptive seating as an intervention for individuals with CP, including modifications to the seat to back support angle of the wheelchair (Chung, Evans, Lee, Lee, Rabbani, Roxborough, & Harris, 2008). There is disagreement about the appropriate orientation of the seat to back support angle, but there is agreement in how tilt or recline features influence postural control of individuals with CP (McNamara & Casey, 2007). People with CP have different impairments that affect their postural stability, which means the design of the wheelchair must be unique to each individual (Chung, Evans, Lee, Lee, Rabbani, Roxborough, & Harris, 2008; Desroches, Aissaoui, & Bourbonnais, 2006).

Despite the fact that cerebral palsy is a lifelong disability, the literature has mostly concentrated on childhood, but in recent years, researchers started to investigate adults

with CP (Sandström, 2009). This study exams the effect of wheelchair seat to back support angle adjustment on head, neck, and shoulder posture in adult people with cerebral palsy who are non-ambulatory and use a wheelchair as their mobility device.

## **Methods**

### ***Study Design***

A cross-sectional study was conducted on subjects with cerebral palsy who are able to sit in a wheelchair. All subjects were screened for inclusion and exclusion criteria at baseline.

### ***Subjects***

This study was approved by the Institutional Review Board (IRB) at Loma Linda University (LLU) and conducted at Nichol Hall room A640/A620 at Loma Linda University at the School of Allied Health Professions (SAHP), Department of Physical Therapy. The participation of all subjects was voluntary, and written informed consent was obtained from subjects before commencing the study.

Nine subjects were recruited from San Bernardino and Riverside Counties by word of mouth or by phone, who were male or female between the ages of 18 and 45 old. Subjects were screened using an inclusion and exclusion questionnaire. Subjects were included if they diagnosed with (quadriplegic) spastic cerebral palsy, hip and knee flexion of at least 90 degrees, frontal plane symmetry, and able to follow directions. Subjects were excluded if they had bony deformities such as obvious scoliosis with rib hump or severe kyphosis. Also, they were excluded if they had pressure sores on the



buttocks because that would eliminate weight bearing during sitting.

Subjects were asked to wear suitable clothing, such as a tank top that will allow their neck and shoulders to be exposed for the photographs and to tie up long hair as needed.

### *Equipment*

We used Invacare's Solara tilt and recline manual wheelchair, with Freedom Designs' linear back and seat (10-cm thickness of foam covered with Dartex), a pelvic strap attached at a 45° angle to the seat, and 90° foot hangers and footplates attached. This wheelchair could be positioned at the three seat to back support angles tested in this study. An angle finder tool, purchased at local hardware store, was attached to the back support of the wheelchair. Also, a smart phone (iPhone 6 plus), tripod, and cellphone adaptor were used to take photographs.

Coach's Eye (CE), a performance-enhancing smart device application with an angle tool, was used to evaluate movement and posture. Coach's Eye is a valid program to evaluate posture angles as we found in previous study on able subjects (Alkhateeb, Forrester, Daher, & Alonazi, 2016).

### *Procedures*

The wheelchair was positioned sideways in front of a white sheet suspended from the ceiling. A rectangle was taped out on the ground using 1.88 inch-wide (4.78 centimeter) duct tape to outline the same dimensions as the wheelchair's ground footprint, in order to insure consistent placement of the front and rear wheels throughout

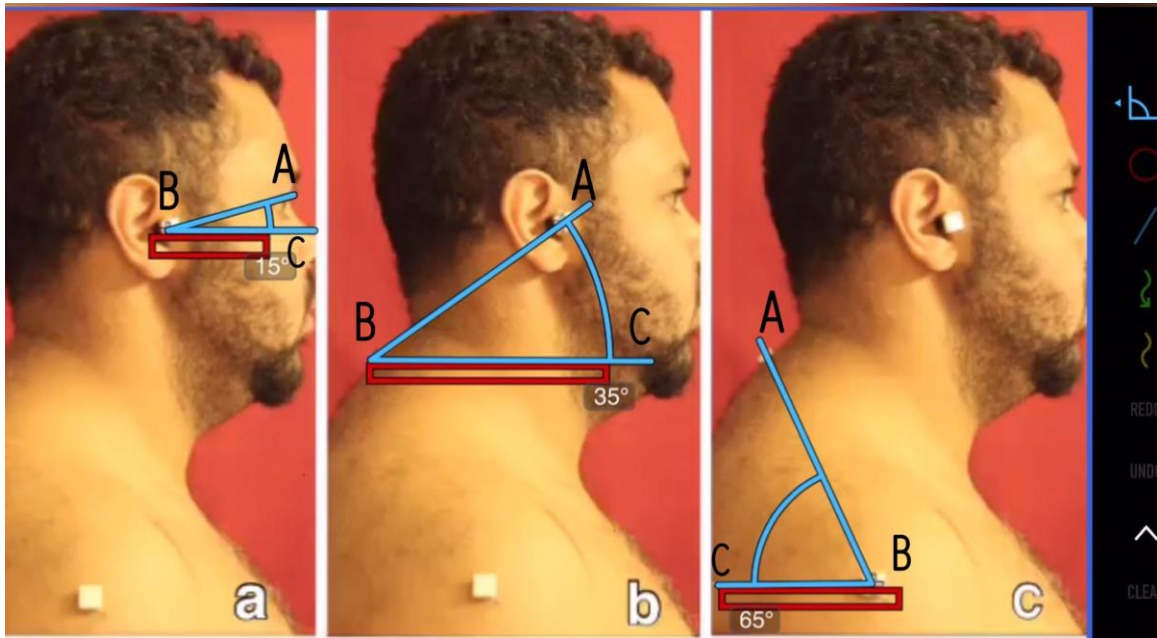
the study. The angle finder was secured by Velcro to an L-bracket attached to the top left edge of the back support. The front and back of the seat was measured, using a steel tape measure to insure it was horizontal to the ground. We mounted a smart phone (iPhone 6 plus) on a tripod using a cellphone adaptor, setting the tripod so that the camera lens of the phone was 47 inches (1.2 meter) from and level to the ground, at 2 meters lateral to the midpoint of the wheelchair on its left side. The midpoint was determined using the left linear tape mark of the rectangle on the ground. This positioning allowed for head and shoulder to be fully captured in each photograph taken.

Subjects transferred by two physical therapists and their caregiver to sat in the wheelchair positioned at the 90° seat to back support angle, with their buttocks all the way back to the rear, touching the lower portion of the back support. This position was secured by firmly tightening the pelvic strap. Subjects' feet were positioned on the footplates. A 6-foot (1.83 meter) tall mirror, mounted on wheels was placed 1 meter in front of the subjects. White reflective markers (Foam Mounting Squares), 1 cm square, were placed on 3 landmarks; tragus of ear, C7 spinous process, and head of the humerus (midpoint).

The camera function of the iPhone 6 plus was turned on. Subjects were asked to take a deep breath and exhale to facilitate relaxation. Then they were asked to look to the ceiling, then look to the ground, and finally look into their own eyes in the mirror positioned in front of them, in order to reproduce the Natural Headrest Position (NHP) as described by (Weber, 2012). Subjects were asked to stay in position for the 3 seconds it took to take a short video.

The back support was reclined to 100°, as verified by the angle finder, and the sequential procedure was repeated as stated above, while the buttocks continued to be secured by the pelvic strap and did not move forward. The back support was reclined to 110° and this procedural sequence was repeated one more time.

Coach's' Eye photographic analysis was done using the following three steps: 1) draw a rectangle parallel to the horizontal line of each body angle (parallel to the line connecting points B and C) to make sure that the horizontal line of each angle is straight and horizontal. Next, 2) draw the actual horizontal line of the measured angle immediately above the rectangle connecting point B (tragus of the ear for SHA, C7 spinous process for CVA, and head of the humerus, midpoint) to point C (horizontal line anteriorly for SHA and CVA, horizontal line posteriorly for SA). Finally, 3) draw the other line of the angle connecting point B to point A (canthus of the eye for SHA, tragus of the ear for CVA, C7 spinous process for SA) (Figure 1).



**Figure 1.** Measuring the three body angles: a) sagittal head angle (SHA), b) cervical angle (CVA), and c) shoulder angle (SA).

### ***Data Analysis***

Data was analyzed using the Statistical Package for the Social Sciences (SPSS) version 23.0. The general characteristics of the subjects were summarized using means and standard deviations for quantitative variables, and frequencies and relative frequencies for categorical variables. The normality of the variables was examined using Kolmogorov-Smirnov test. One way repeated measures analysis of variance (ANOVA) was used to assess changes in the postures of sagittal head angle (SHA), cervical angle (CVA), and shoulder angle (SA) angles at 90°, 100° and 110° back rest angles of wheelchair. Post hoc comparisons were conducted using the least significance difference (LSD) test. The  $\alpha$  level was set at  $p \leq 0.05$ .

### **Results**

Nine subjects, mean age  $31.0 \pm 8.8$  years participated in the study. Seventy eight percent of the subjects were males ( $n= 7$ ). The distribution of the three body angles of sagittal head angle, cervical angle, and shoulder angle at 90°, 100° and 110° seat to back support angles of wheelchair were approximately normal ( $p > 0.05$ ). There was a significant difference in mean sagittal head angle among the different seat to back support angle of wheelchair (90, 100 and 110 degrees) (mean  $\pm$  standard error (SE);  $23.0 \pm 2.8$  vs.  $22.0 \pm 2.7$  vs.  $19.0 \pm 2.3$  respectively,  $p = 0.03$ ). Results of post hoc comparisons using the LSD test showed that there was a significant difference in mean sagittal head angle between 90 and 110 degrees ( $p = 0.03$ ) and between 100 and 110 degrees ( $p = 0.03$ ). In addition, there was a highly significant difference in mean cervical angle among the different angles of seat to back support (mean  $\pm$  SE;  $35.3 \pm 3.5$  vs.  $40.1$

$\pm 4.2$  vs.  $42.9 \pm 4.1$  respectively,  $p < 0.001$ ). Results of the post hoc comparisons using LSD test showed that there was a significant difference in mean cervical angle between 90 and 100 degrees ( $p = 0.02$ ), between 90 and 110 degrees ( $p < 0.01$ ), and between 100 and 110 degrees ( $p = 0.02$ ). However, there was no significant difference in mean shoulder angle among the different seat to back support angles of wheelchair (mean  $\pm$  SE;  $46.7 \pm 5.2$  vs.  $46.2 \pm 5.8$  vs.  $45.2 \pm 7.4$  respectively,  $p = 0.83$ ; see Table 1).

**Table 1.** Mean (SE) of three different body angles by seat to back support angle (degrees) (n=9).

Seat to Back support Angle	Body Angle		
	SHA	CVA	SA
90° (2.8)*	23.0	35.3 (3.5)* ^	46.7 (5.2)
100°	22.0 (2.7)*	40.1 (4.2)*	46.2 (5.8)
110°	19.0 (2.3)	42.9 (4.1)	45.2 (7.4)
P-value <sup>a</sup>	0.03	<0.001	0.83

Abbreviations: SE, standard error; SHA = sagittal head angle; CVA = cervical angle; SA = shoulder angle.

\*Significant change from 110°

^ Significant change from 100°

<sup>a</sup> p-values for the null hypothesis that there is a no difference across the three angles

## Discussion

Through recent years, adaptive seating has been studied as an assistive postural device to help individuals with neuromotor impairments who have difficulty maintaining posture against gravity (Fife, Roxborough, Armstrong, Harris, Gregson, & Field, 1991). Adaptive seating helps individuals with mobility impairments improve their postural control, which is the ability to control the body's position in space to secure stability and orientation while sitting (Chung, Evans, Lee, Lee, Rabbani, Roxborough, & Harris, 2008). Multiple studies have been conducted on individuals with cerebral palsy (CP), and have shown that improvement in sitting posture and stability promotes functional activities (Liao, Yang, Hsu, Chan, & Wei, 2003), (Chung, Evans, Lee, Lee, Rabbani, Roxborough, & Harris, 2008). A useful technique to improve postural control and stability in individuals with CP during sitting is modification of the seat to back support angle of the wheelchair (Chung, Evans, Lee, Lee, Rabbani, Roxborough, & Harris, 2008). Dicianno (2009) reported that while the pelvis is supported in sitting, the thigh to trunk angle must be opened to at least 110° to maintain balanced spinal curvatures (Dicianno, Arva, Lieberman, Schmeler, Souza, Phillips, Lange, Cooper, Davis, & Betz, 2009).

In general, sitting with as much contact as possible with the chair surface improves sitting posture and functional stability (Neville, 2005). Typically, people with moderate to severe CP have full contact back support that reach to the top of the thoracic spine. These full contact back support are used for attachment of anterior and lateral trunk supports, as well as headrests, and exert an effect on the posture of the thoracic spine, which in turn affects the posture of the head, neck and shoulder.

This study examined the effect of wheelchair seat to back support angle



adjustments on head, neck, and shoulder posture in people with cerebral palsy, who are non-ambulatory and use a wheelchair as their mobility device. Three angles were selected to be studied; sagittal head angle (SHA), cervical angle (CVA), and shoulder angle (SA), because they are most frequently evaluated in literature (Ruivo, Pezarat-Correia, & Carita, 2014).

The current study found a significant difference in mean posture of the sagittal head angle (SHA) among the three different positions of seat to back support angles. The closest posture to neutral alignment of the head in relation to the neck was with the seat to back support set at 110°. Clinicians confirm that reclining the seat to back support angle of a wheelchair helps to align the head and trunk over the pelvis, thus avoiding the forward posture seen with an upright (90°) back support position (Brad E. Dicianno, Juliana Arva, Jenny M. Lieberman, Mark R. Schmeler, Kevin Phillips, Rosemarie, Kim Davis, & Betz, 2008) An appropriate head position in subjects with a neuromuscular disorder such as CP provides improved visual orientation, line of sight, breathing, swallowing, heart rate, communication, as well as minimizes abnormal tone and reflexes (Fitzsimmons, 2014; Kreutz, 1997), which is referred to as SHA in this study.

Our study determined that there was a highly significant difference in head posture (i.e. cervical angle) among the different seat to back support angles. The closest posture to neutral alignment for head (CVA) was with the seat to back support set at 110°. This allows for a larger cervical angle (CVA), which correlates with the head moving back toward neutral (Diab & Moustafa, 2012). Reclining the seat to back support allows gravity to facilitate repositioning the head closer to an neutral position

(Sommerfreund, 1995). In this study, both SHA and CVA angles improved simultaneously with the seat to back support angle set backward from 90°.

The current study found no significant difference in mean posture of shoulder angle (SA) among the three different positions of seat to back support angles. This indicates there is no preferable position for obtaining a more neutral shoulder posture during sitting by changing the wheelchair seat to back support angle. The shoulders are not directly attached to the spine the way the head is, therefore are not as strong of an indicator of upright axial posture as the head. We can speculate that adult subjects with moderate to severe CP, who sit in wheelchairs for mobility for most of their day, have tight anterior trunk muscles. This may also account for the lack of change in SA.

The three body angles (SHA, CVA, SA) have been used as an indicator that the muscles and ligaments of the head and neck are experiencing increased mechanical load (van Niekerk, Louw, Vaughan, Grimmer-Somers, & Schreve, 2008). These angles have also been used for studying ergonomic corrections in office chairs and car seats, as well as for assessment of issues with backpack, prolonged computer, and cell phone use (Donald D. Harrison & Harrison, 1999; Horton, 2010), (Chansirinukor, Wilson, Grimmer, & Dansie, 2001) (Ruivo, Pezarat-Correia, & Carita, 2014), (Kang, Park, Lee, Kim, Yoon, & Jung, 2012). However, these three body angles have not been studied on people with CP who sit in wheelchairs for most of their daily activities.

Good sitting position refers to having the head and trunk upright with midline orientation close to vertical (Campbell, Vander Linden, & Palisano, 2000). Although 90°-90°-90° positioning (i.e. degrees of flexion at the hips, knees, and ankles) has been promoted in the past, when using a full contact back support, 90° at the hips does not

allow the COM of the head to naturally position over the pelvis. Individuals with moderate to severe cerebral palsy usually find it hard to sit with good stability and maintain a vertical upright posture. Observationally, when people with moderate to severe CP sit with a full contact back support at a 90° angle, they usually compensate by leaning forward or to the side because they cannot get the COM of their head comfortably over their pelvis, the BOS. Opening the seat to back support angle of the wheelchair, allows them to bring the COM of the head and trunk backwards over their BOS, therefore allowing postural muscles to relax (Kreutz, 1997) (Neville, 2005).

According to this study, the closest posture to neutral alignment for the head (SHA) and neck (CVA) was found with the seat to back support set at a 110°. These results cannot be generalized to all individuals with cerebral palsy, as seating intervention applications have to be chosen on a case-by-case basis.

### **Limitations**

There were some limitations in this study, such as subjects were seated in the testing position on wheelchair at study time only. Also, global generalizing of the study findings is limited because the small sample size, and persons with cerebral palsy have wide range of variety in functional and postural impairments.

### **Conclusion**

Base on the results of this study, the most appropriate sagittal head and cervical angles were obtained when the back support was set at 110°. However, there was no significant difference in mean posture of shoulder angle among the different angles of back support.

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## CHAPTER FOUR

### DISCUSSION

In this study three angles were selected sagittal head angle (SHA), cervical angle (CVA), and shoulder angle (SA) because they are most frequently evaluated in the literature (Ruivo, Pezarat-Correia, & Carita, 2014). The first part was conducted on abled-bodied subjects to find if there is any alteration of their posture in relation to the change in seat to back support angle, as well as to test the concurrent validity and inter-rater reliability of the smart device Coach's Eye application. The second part examined the effect of wheelchair seat to back support angle adjustments on head, neck, and shoulder posture in people with cerebral palsy, who are non-ambulatory and use a wheelchair as their mobility device.

Neutral posture is described as a vertical relationship between anatomical structures, which means perpendicular alignment of the ear, shoulder, and hip in the sagittal plane; also, hips and knees positioned horizontally at the same level (Harrison, Harrison, Croft, Harrison, & Troyanovich, 1999). When natural spinal curvatures are maintained, it minimizes gravitation pull on the soft tissues of the vertebral column. Supporting the thoracic and lumbar spine during sitting prevents excessive flexion of both the thoracic and lumbar regions (Pynt, Higgs, & Mackey, 2001). To have good postural stability, the trunk and head need to maintain center of mass (COM) over base of support (BOS) (Westcott, Lowes, & Richardson, 1997).

In general, sitting with as much contact as possible with the chair surface improves sitting posture and functional stability (Neville, 2005). A useful technique to improve postural control and stability in individuals with CP during sitting is



modification of the seat to back support angle of the wheelchair (Chung, Evans, Lee, Lee, Rabbani, Roxborough, & Harris, 2008). Dicianno (2009) reported that while the pelvis is supported in sitting, the thigh to trunk angle must be opened to at least  $110^{\circ}$  to maintain balanced spinal curvatures (Dicianno, Arva, Lieberman, Schmeler, Souza, Phillips, Lange, Cooper, Davis, & Betz, 2009). Through recent years, adaptive seating has been studied as an assistive postural device to help individuals with neuromotor impairments who have difficulty maintaining posture against gravity (Fife, Roxborough, Armstrong, Harris, Gregson, & Field, 1991).

For abled subjects, there was no change in sagittal head angle (SHA) among the three different positions of seat to back support angles of this study. This result indicates there is no preferable position for maintaining head posture close to neutral alignment during sitting. Also, the closest to neutral alignment for head posture (CVA) was with the seat to back support angle set at  $110^{\circ}$ , and the furthest from neutral alignment was with the seat to back support angle set at  $90^{\circ}$ . There was no significant difference between  $100^{\circ}$  and  $110^{\circ}$ . Moreover, shoulder angle (SA) readings for all subjects showed some degree of protraction in all three positions of this study. There was less SA with seat to back support angle set at  $90^{\circ}$ , however, there was no difference between  $100^{\circ}$  and  $110^{\circ}$ .

Contemporary life style's pull the head in a forward direction in an attempt to get closer to objects, such as cell phones, computers, video games, and even books, which leads to extra weight on neck and upper back tissues. In order to hold the head forward, it seems evident that continuous isometric contractions of neck and upper back muscles are needed. Sitting with the seat to back support angle at a right angle ( $90^{\circ}$ ) for long periods of time, transfers COM of the head anteriorly and may lead to change in sitting stability.

Observationally, abled subjects in this study compensated by retracting their shoulders to bring the COM of the head back toward BOS. When opening the seat to back support angle, the head posture realigned close to neutral alignment. Speculatively, this is most likely due to allowing the COM of the head to be balanced over the BOS, and compensatory posture changes are no longer needed.

For subjects with cerebral palsy, there was a significant difference in mean posture of the sagittal head angle (SHA) among the three different positions of seat to back support angles. The closest posture to neutral alignment of the head in relation to the neck was with the seat to back support angle set at 110°. Also, there was a highly significant difference in head posture (CVA) among the different seat to back support angles. The closest posture to neutral alignment for head (CVA) was with the seat to back support angle set at 110°. Moreover, there was no significant difference in mean posture of shoulder angle (SA) among the three different positions of seat to back support angles. This indicates there is no preferable position for obtaining a more neutral shoulder posture during sitting by changing the wheelchair seat to back support angle.

Good sitting position refers to having the head and trunk upright with midline orientation close to vertical (Campbell, Vander Linden, & Palisano, 2000). Individuals with moderate to severe cerebral palsy usually find it hard to sit with good stability and maintain a vertical upright posture. Although 90°-90°-90° positioning (i.e. degrees of flexion at the hips, knees, and ankles) has been promoted in the past, when using a full contact seat to back support, 90° at the hips does not allow the COM of the head to naturally position over the pelvis. Observationally, when people with moderate to severe CP sit with a full contact seat to back support at a 90° angle, they usually compensate by

leaning forward or to the side because they cannot get the COM of their head comfortably over their pelvis, the BOS. Opening the seat to back support angle of the wheelchair, allows them to bring the COM of the head and trunk backwards over their BOS, therefore allowing postural muscles to relax (Kreutz, 1997) (Neville, 2005).

For validity and inter-rater reliability, results when using ImageJ computer program and Coach's Eye smart devices application were consistent, which means that the CE program has high criterion validity. Based on this finding, the physical therapists can use the CE in their evaluation of their patients' postures. Advantages of the CE are: it is easy to use, it is affordable (~ \$20.00), and photos do not need to be downloaded to a computer. Also, it is an application on smart devices and tablets, which make the assessment and communication between the therapist and the patients easy and timely. In this study, two physical therapists participated as raters, each performing readings of the angles separately, using both programs. The results of this study demonstrated high inter-rater agreement.

For the cervical rotation part of this study, there was no significant difference or improvement in cervical rotation range among the three angles of posture.

### **Conclusion**

Based on the results of this study, there is no one seat to back support angle that leads to improved sitting posture in all three body angles sagittal head angle (SHA), cervical angle (CVA), and shoulder angle (SA) at the same time for abled subjects. When choosing an appropriate seat to back support angle in any seating device, one must consider the needs of each subject, their habitual work, and life sitting postures. For

subjects with cerebral palsy the closest posture to neutral alignment for the head (SHA) and neck (CVA) was found with the seat to back support angle set at a 110°. These results cannot be generalized to all individuals with cerebral palsy, as seating intervention applications have to be chosen on a case-by-case basis. There is no one best sitting posture in a seating device, the most useful sitting posture corresponds with a neutral spine, which minimizes muscular tension (O'Sullivan, O'Sullivan, O'Sullivan, & Dankaerts, 2012).

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## APPENDIX A

### EVALUATION FORM FOR ABLED SUBJECTS



LOMA LINDA UNIVERSITY  
School of Allied Health Professions

Name: \_\_\_\_\_ # \_\_\_\_\_ Date: \_\_\_\_\_

D.O.B: \_\_\_\_\_ Gender:  Male  Female

#### **History of Back or Neck Disease**

Any history of craniofacial, cervical, shoulder, low back injury or neurologic disease

no  yes

#### **Musculoskeletal Disease**

Any history of shoulder surgery, current shoulder pain limiting activities.

no  yes

#### **Any Spinal Abnormalities**

no  yes

#### **Cervical or thoracic fracture**

no  yes

#### **Displayed functional or structural scoliosis**

no  yes

#### **Excessive thoracic kyphosis**

no  yes

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909-558-4632 · 800-422-4558 · fax 909-558-0459 · www.llu.edu/llu/sahp/pt

## APPENDIX B

### EVALUATION FORM FOR SUBJECTS WITH CEREBRAL PALSY



LOMA LINDA UNIVERSITY  
School of Allied Health Professions

Name: \_\_\_\_\_ # \_\_\_\_\_ Date: \_\_\_\_\_

Age: \_\_\_\_\_ Gender:  Male  Female

Rt. Hip flexion at least 90°  yes  no

Lf. Hip flexion at least 90°  yes  no

Rt. Popliteal angle at least 90°  yes  no

Lf. Popliteal angle at least 90°  yes  no

Rt. Foot plantigrade  yes  no

Lf. Foot plantigrade  yes  no

Frontal plane symmetry:

- Obvious scoliosis with rib hump  yes  no

- Severe kyphosis  yes  no

Pressure sores on buttocks  yes  no

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## APPENDIX C

### INFORMED CONSENT FOR ABLED SUBJECTS



LOMA LINDA UNIVERSITY  
School of Allied Health Professions

#### **“Effects of Adjustments to Wheelchair Backrest Angle on Head, Neck, and Shoulder Postures in Abled Subjects”**

Principal Investigator Bonnie Forrester, PT, M.S., D.Sc., PCS Office (909) 558-4632

You are invited to take part in a research study about sitting posture in a wheelchair. You are free to choose whether or not to take part in the study. Please carefully read and understand what the study involves before you agree.

#### **STUDY PURPOSE**

This study will evaluate the use of apps to help physical therapists look how people sit. We will measure the difference in upper neck movement range of motion between seat back angles. To be in the study, you need to be between 18 and 45 years old and be in good health. We will sign up 30 people. You cannot participate in this study if you have any of the following:

- History of head, neck, shoulder, low back injury, or neurologic disease.
- Musculoskeletal diseases, such as a history of shoulder surgery, or current shoulder pain.
- Any spinal abnormalities.

#### **STUDY PROCEDURES**

You will come to Nichol Hall room A640/A620 at Loma Linda University to start the study. The participation for this study will last up to 1 hour for 1 day. If you meet the screening requirements and you choose to take part in the study, then the following will take place:

- A sticky reflective mark will be placed on outer ear, last neck vertebra, and shoulder.
- Photographs will be taken by digital camera in each position of backrest angles 90°, 100° and 110°. Wheelchair angles will be determined by using Angle Finder tool.
- Measurements of the three body angles will be taken in all three backrest angles of wheelchair; these angles are head, neck and shoulder.

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### **POSSIBLE RISKS AND DISCOMFORTS**

The risks for this study are minimal. A mild to moderate discomfort (soreness) may be felt in the upper neck muscles while changing head and neck angles. In order for us to minimize the risk, we will evaluate you to make sure that you will be able to sit in the wheelchair. Also, we will adjust you to make sure that you are free from any pain or movement restrictions that can produce any risk or discomfort. There will be a physical therapist monitoring you during study. Any photos that will be published will have face cover up.

### **BENEFITS**

You will not directly benefit from participating in this study, but the study should give us a better understanding of how using apps to measure changes in head, neck, and shoulder angles effects how you sit.

### **PARTICIPANT RIGHTS**

You may leave the study at any time. If at any time you feel tiredness or discomfort beyond what you are willing to do, just tell the person working with you that you want to stop.

Participation Rights Summary:

- You are free to withdraw from this study at any time. If you decide to withdraw from this study you should notify the research team immediately. The research team may also end your participation in this study if you do not follow instructions, or miss the scheduled visit, or if your safety and welfare are at risk.
- Likewise, your participation in the study may be stopped by the study staff/investigator for any reason without your agreement.

### **RESEARCH RELATED INJURY**

If you require medical assistance, your personal physician or local emergency room should be contacted. If you feel too tired or if you are injured, you may need to be withdrawn from the study, even if you would like to continue. The research team will make this decision and let you know if it is not possible for you to continue. The decision may be made to protect your safety and welfare.

If you are injured or become ill while taking part in this study:

- If the situation is a medical emergency call **911** or go to the nearest emergency room. Then, notify the research doctor as soon as you can.
- For a non-emergency injury or illness, notify your research doctor as soon as you can.

To report any injury related to participation in the study, you should call Bonnie Forrester, DSc, Study Coordinator at (909) 558-4632, Ext. 47320, during daytime hours (8:00 am-5:00 pm PST).

You and your insurance company will be billed at the usual charge for the treatment of any research-related injuries, illnesses, or complications. You might still be asked to pay whatever your insurance does not pay.

Also, no funds have been set aside, nor any plans made to compensate you for time lost for work, disability, pain or other discomforts resulting from your participation in this research. You do not give up any of your legal rights by participating in the study.

**CONFIDENTIALITY**

All records will be confidential and stored in a locked cabinet in a locked room. We will not disclose your participation without your written permission. Any publication resulting from this study will refer to you by ID number and not by your name.

**COSTS/COMPENSATION**

There is no cost for participating in these studies. You will receive a \$25 gift card for completion of the study. In order to receive such payment, you may be asked to provide your home address and/or your Social Security number.

**IMPARTIAL THIRD PARTY**

If you wish to contact a third party not associated with the study for any questions or a complaint, you may contact the Office of Patient Relations at Loma Linda University, Loma Linda University Medical Center, Loma Linda, California 92354. Phone (909) 558-4647. [patientrelations@llu.edu](mailto:patientrelations@llu.edu)

**INFORMED CONSENT STATEMENT**

I have read the contents of the consent form and PHI and have listened to the verbal explanation given by the investigator. My questions regarding the study have been answered to my satisfaction. I hereby give voluntary consent to participate in the study described here. Signing this form does not waive my rights nor does it release the responsibilities of the principal investigator, Bonnie Forrester DSc. or Loma Linda University of their responsibilities. I may call Dr. Bonnie Forrester during routine office hours at (909) 558-4632, Ext. 47320 or leave a voice mail message at this number during non- office hours.

\_\_\_\_\_  
Signature of subject

\_\_\_\_\_  
Date

\_\_\_\_\_  
Authorized representative

\_\_\_\_\_  
Date

**INVESTIGATOR'S STATEMENT**

I have reviewed the contents of the consent form and the PHI with the person signing above. I attest that the requirements for informed consent for the medical research project described in this form have been satisfied, that I have discussed the research project with the subject and explained to him or her in non-technical terms all of the information contained in this informed consent form, including any risks and adverse reactions that may reasonably be expected to occur. I further certify that I encouraged the subject to ask questions and that all questions asked were answered. I will provide the subject with a signed and dated copy of this consent form.

Signature of investigator \_\_\_\_\_

Phone Number \_\_\_\_\_ Date \_\_\_\_\_

## APPENDIX D

### INFORMED CONSENT FOR SUBJECTS WITH CEREBRAL PALSY



LOMA LINDA UNIVERSITY  
School of Allied Health Professions

#### “Effect of Adjustments to Wheelchair Backrest Angle on Head, Neck, and Shoulder Postures in Subjects with Cerebral Palsy”

Principal Investigator Bonnie Forrester, PT, M.S., D.Sc., PCS Office (909) 558-4632

You are invited to take part in a research study about sitting posture in a wheelchair. You are free to choose whether or not to take part in the study. Please carefully read and understand what the study involves before you agree.

#### STUDY PURPOSE

The study is about changes in head, neck and shoulder postures by using adjustments in backrest angle of a wheelchair. We will sign up 20 people.

You must meet the following requirements to be in the study:

#### Inclusion Requirements:

- Between 18 and 49 years old and diagnosed with cerebral palsy.
- Hip and knee flexion (bend) of at least 90 degrees.
- Body posture similarities from front view.
- Able to sit in a 16” seat depth wheelchair with hips and knees flexed.
- Able to follow directions.

#### Exclusion Requirements:

You cannot participate in this study if you any of the following:

- Hip flexion contractures no greater than 50 degrees.
- Boney deformities.
- Pressure sores that would exclude weight bearing on the buttocks.

Loma Linda University  
Adventist Health Sciences Center  
Institutional Review Board  
Approved 11/2/15  
# 515006-7  
Joni Lamy  
4/1/2016

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### STUDY PROCEDURES

You will come to Nichol Hall room A640/A620 at Loma Linda University to start the study. It is provided with handicapped access.

The participation for this study will last up to 1 hour for 1 day.

If you meet the screening requirements and you choose to take part in the study, then the following will take place:

- A sticky reflective mark will be placed on outer ear, last neck vertebra, and shoulder.
- Photographs will be taken by digital camera in each position of backrest angles 90°, 100° and 110°. Wheelchair angles will be determined by using Angle Finder tool.
- Measurements of the three body angles will be taken in all three backrest angles of wheelchair; these angles are head, neck and shoulder.

### POSSIBLE RISKS AND DISCOMFORTS

The risks for this study are minimal. A mild to moderate discomfort (soreness) may be felt in the upper neck muscles while changing head and neck angles. In order for us to minimize the risk, we will evaluate you to make sure that you will be able to sit in the wheelchair. Also, we will adjust you to make sure that you are free from any pain or movement restrictions that can produce any risk or discomfort. There will be a physical therapist monitoring you during study. Any photos that will be published will have face cover up.

### BENEFITS

You will not directly benefit from participating in this study, but the study should give us a better understanding of how using adjustments in back seat angle to improve head, neck and shoulder postures in sitting position on wheelchair.

### PARTICIPANT RIGHTS

You may leave the study at any time. If at any time you feel tiredness or discomfort beyond what you are willing to do, just tell the person working with you that you want to stop.

Participation Rights Summary:

- You are free to withdraw from this study at any time. If you decide to withdraw from this study you should notify the research team immediately. The research team may also end your participation in this study if you do not follow instructions, or miss the scheduled visit, or if your safety and welfare are at risk.
- Likewise, your participation in the study may be stopped by the study staff/investigator for any reason without your agreement.

Loma Linda University  
Adventist Health Science Center  
Institutional Review Board  
Approved 11/2/15 Void after 4/1/2016  
#5150067 Chair *Shari Leary*

## RESEARCH RELATED INJURY

If you require medical assistance, your personal physician or local emergency room should be contacted. If you feel too tired or if you are injured, you may need to be withdrawn from the study, even if you would like to continue. The research team will make this decision and let you know if it is not possible for you to continue. The decision may be made to protect your safety and welfare.

If you are injured or become ill while taking part in this study:

- If the situation is a medical emergency call 911 or go to the nearest emergency room. Then, notify the research doctor as soon as you can.
- For a non-emergency injury or illness, notify your research doctor as soon as you can.

To report any injury related to participation in the study, you should call Bonnie Forrester, DSc, Study Coordinator at (909) 558-4632, Ext. 47320, during daytime hours (8:00 am-5:00 pm PST).

You and your insurance company will be billed at the usual charge for the treatment of any research-related injuries, illnesses, or complications. You might still be asked to pay whatever your insurance does not pay.

Also, no funds have been set aside, nor any plans made to compensate you for time lost for work, disability, pain or other discomforts resulting from your participation in this research. You do not give up any of your legal rights by participating in the study.

## CONFIDENTIALITY

All records will be confidential and stored in a locked cabinet in a locked room. We will not disclose your participation without your written permission. Any publication resulting from this study will refer to you by ID number and not by your name.

## COSTS/COMPENSATION

There is no cost for participating in these studies. You will receive a \$50 gift card for completion of the study. In order to receive such payment, you may be asked to provide your home address and/or your Social Security number.

## IMPARTIAL THIRD PARTY

If you wish to contact a third party not associated with the study for any questions or a complaint, you may contact the Office of Patient Relations at Loma Linda University, Loma Linda University Medical Center, Loma Linda, California 92354. Phone (909) 558-4647. [patientrelations@llu.edu](mailto:patientrelations@llu.edu)

Loma Linda University  
Adventist Health Science Center  
Institutional Review Board  
Approved 11/2/15 Void after 4/1/2016  
# 5150067 Chair *Lori Looney*

**INFORMED CONSENT STATEMENT**

I have read the contents of the consent form and PHI and have listened to the verbal explanation given by the investigator. My questions regarding the study have been answered to my satisfaction. I hereby give voluntary consent to participate in the study described here. Signing this form does not waive my rights nor does it release the responsibilities of the principal investigator, Bonnie Forrester DSc. or Loma Linda University of their responsibilities. I may call Dr. Bonnie Forrester during routine office hours at (909) 558-4632, Ext. 47320 or leave a voice mail message at this number during non- office hours.

\_\_\_\_\_  
Signature of subject  
\_\_\_\_\_  
Date

\_\_\_\_\_  
Authorized representative  
\_\_\_\_\_  
Date

**INVESTEGATOR'S STATEMENT**

I have reviewed the contents of the consent form and the PHI with the person signing above. I attest that the requirements for informed consent for the medical research project described in this form have been satisfied, that I have discussed the research project with the subject and explained to him or her in non-technical terms all of the information contained in this informed consent form, including any risks and adverse reactions that may reasonably be expected to occur. I further certify that I encouraged the subject to ask questions and that all questions asked were answered. I will provide the subject with a signed and dated copy of this consent form.

Signature of investigator \_\_\_\_\_

Phone Number \_\_\_\_\_ Date \_\_\_\_\_

*Loma Linda University  
Adventist Health Science Center  
Institutional Review Board  
Approved 11/2/15 Void after 4/1/2016  
#5150067 Chair *Travis Looney**