The Use of a Lighted Tilted Frame with Individuals Who Had a Cerebral Vascular Accident

A Capstone Project for PTY 769
Presented to the Faculty of the Department of Physical Therapy
Sage Graduate School

In Partial Fulfillment
of the Requirements for the Degree of
Doctor of Physical Therapy

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May, 2009

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Abstract

Objective: The purpose of this study was to investigate the effect of a lighted tilted frame on symmetrical weight bearing in 2 individuals who have had a cerebral vascular accident (CVA). **Design**: Single-subject design with 2 subjects, one who had a right CVA and the other had a left CVA. **Methods**: Subjects had 6 weeks of the intervention. The intervention consisted of standing for 15 minutes without visual stimulation during the A (control) phase, standing with a lighted frame tilted towards the subject's involved side for 15 minutes during the B phase and standing with a lighted frame tilted toward the subject's uninvolved side for 15 minutes during the C phase. The subjects were examined transferring from sit to stand on the EquiTest® System before and after each intervention to determine their left/right symmetry in standing. Balance and gait assessments were performed before and after each phase. **Data Analysis:** Acceleration line, mean level and two standard deviation band width method were used to analyze the data. **Results:** Both subjects had more weight on their uninvolved lower extremities during the A and B phases and had a more symmetrical stance during the C phase. **Conclusion:** These results may assist in providing visual stimulation to improve symmetrical standing in a clinical setting to patients who have had a CVA.

Key Words: cerebral vascular accident; hemiparesis; asymmetry; sit to stand; stroke; lighting; EquiTest®; balance; vision

Introduction

A cerebral vascular accident (CVA) is defined as "a devastating vascular event that results in damage to the surrounding brain tissue."[1] Each year approximately 700,000 individuals will have a CVA, which is the leading cause of serious, long-term disability in adults, and is the third leading cause of death in the United States.[1,2,3] In 2007 there were 4.7 million CVA survivors, 2.3 million of them were men and 2.4 million were women.[2]

Some common impairments associated with CVA are; decreased motor function, range of motion (ROM), sensation, symmetry, and abnormal muscle tone.[1] These are impairments that commonly affect only one side of the body, which is known as hemiparesis. Other impairments resulting from a CVA are decreased balance, visual field deficits, and impaired coordination.[1]

Following a CVA, hemiparesis remains a long term effect in almost 50% of the CVA survivors.[1] A study by Chou et al[4] performed research with individuals who have hemparesis, and results showed that there is an altered weight distribution pattern where less weight is taken through the involved lower extremity (LE) in standing resulting in an asymmetrical posture. With hemiparesis, asymmetrical posture is one of the main problems individuals will face.[5] Asymmetric posture and movement is the most prevalent deficit in stroke-related hemiparesis.[4] This asymmetrical posture will impede the ability to perform independent ambulation and activities of daily living due to impaired balance related to asymmetrical weight bearing.[5,6] Balance impairments can increase an individual's risk for falls and cause them to have difficulty with activities of daily living and gait.[3] Balance control is defined as "the condition in which the internal and external forces acting on the body are evenly distributed so that the center of mass is over its base of support."[7,8] Balance control is often impaired following a CVA and is characterized by an asymmetrical distribution between the LE's.[7] During sit to stand and stand to sit tasks, those with hemiparesis will often put more weight on their uninvolved LE. Reports have shown that this asymmetrical weight bearing may be a contributing factor to falls in those with hemiparesis due to a CVA.[9]

One of the primary goals for the individual with CVA is fall prevention. Many falls that occur with individuals who have had a CVA, occur during activities that involve a change in position such as standing up, sitting down and initiating walking.[9] Approximately 40% of people who have had a CVA will have a serious fall within 1 year.[10] If increased symmetrical weight bearing can be improved by shifting weight to the involved side it will increase balance and decrease risk for falls. Increasing symmetry involves several systems such as; somatosensory, vestibular systems and vision. Following a CVA, central vestibular function, proprioceptive perception and visual perception are impaired.[11]

The somatosensory system includes information from the skin and musculoskeletal systems and provides information about our external environment used in movement control. Consciously, the somatosensory system helps to discriminate between different sensations such as touch, proprioception, pain and temperature and improve our ability to control fine movements. Unconsciously, the somatosensory system provides information which contributes to postural control and movement.[12]

The vestibular system provides sensory information regarding head positions and movements in relation to gravity. The vestibular system is also used for gaze stabilization, posture and balance, and also contributes to the conscious awareness of our body's orientation in space and maintains postural stability during stance and ambulation.[13] The vestibular system is important for balance control especially when there is conflicting information from the visual and somatosensory systems.[14]

Postural control is not only affected by input from the visual system, but also from the environment, proprioceptive and vestibular systems. Postural stability and postural orientation are two aspects of postural control. Postural stability refers to the ability to maintain the body's position in equilibrium.[15] Postural orientation refers to the body's ability to incorporate information about the environment to complete activities.[13]

Posture and gait control is based upon the body's ability to utilize pre-programmed patterns of muscle activation initiated by the vestibular, somatosensory and visual systems. Without appropriate vestibular and somatosensory reference there is a reliance on vision to detect self motion and object motion. When individuals have deficits in the vestibular or somatosensory systems, they make rapid use of visual information for postural reactions.[14]

Vision is important for maintaining balance by providing the nervous system with constant input regarding awareness of the body's movements in space.[16] Visual proprioception allows conscious and unconscious awareness about the environment to guide movement. The body integrates visual proprioception with other systems such as the somatosensory and vestibular systems which are important in maintaining balance. Studies show that following a CVA, individuals are more dependent on their vision for balance.[7,11,17] When individuals have impaired balance they will rely heavily on the visual system, which may be a natural way to compensate for these balance impairments.[17] Bonan et al[17] conducted a study where they assessed vestibular, somatosensory and visual information using the Sensory Organization Test (SOT) to determine if deficits in these systems were the cause of postural imbalance in individuals (n=40) at least 12 months post CVA. They reported individuals with chronic CVA relied heavily on their vision and over time this becomes an automatic response. This reliance may be a result of impairments in the vestibular and somatosensory systems. Bonan et al[17] reported SOT 5 (eyes closed on uneven surface) scores were significantly lower for individuals with right hemispheric lesions (P=0.004) and not significantly lower for left hemispheric lesions. This finding may indicate that individuals with right hemispheric lesions rely more on visual input than those with left hemispheric lesions.

Individuals rely on their visual system for postural stability; if vision is impaired then they are at greater risk for falls due to the decrease in postural stability. Without visual cues, postural stability is decreased and body sway is increased. In a study by Cheng et al[9], when comparing subjects with a CVA (n=33) to aged matched healthy subjects (n=25), the researchers assessed sit to stand performance to determine its relationship to falls in those with a CVA. They concluded that postural sway abnormalities in individuals with hemiparesis may be due to impaired somatosensory, vestibular and visual systems and a poor ability to integrate spatial information.[9]

Postural deficits are common following a stroke and can delay improvements in functional independence secondary to weakness and decreased motor control.[4,18] Chou et al[4] conducted a study in which they assessed postural control during sit to stand and gait in individuals who had a CVA (n=40) compared with age matched healthy individuals (n=22). The participants were seated on an armless, backless chair with their feet parallel and on a force platform (Advanced Mechanical Technology Inc.) which analyzes their anteroposterior and mediolateral sway, vertical forces and their center of pressure (COP). The participants were instructed to rise from sitting at their usual pace. They stood for approximately 30 seconds and were then asked to sit down at their normal pace. Three trials were conducted and analyzed. The results showed that those individuals who had a CVA required greater time to go from sit to stand than their age matched healthy peers ($P < 0.01$). They also reported that the individuals who had a stroke demonstrated a significant increase in mediolateral COP sway. When gait analysis was performed they found that those who had a CVA demonstrated decreased gait velocity, step length, cadence, and single support as well as increased stride time, double support and increased asymmetry. They reported that those who had hemiplegia following a CVA and who could rise from sitting in less than 4.5 seconds or had a maximal vertical force difference of less than 30% of body weight distributed between both lower extremities, they had better gait performance than those who did not. Following a CVA an individual will have weakness of the hemiparetic side and impaired postural control causing the automatic reflex of rising from sitting to become more asymmetric.[4] Cheng et al[9] reported individuals with a CVA who had greater mediolateral COP sway had poor dynamic postural stability and were at a greater risk for falls.

Individuals who have had a CVA will often have asymmetry due to weakness and somatosensory issues as well as difficulty with their vertical orientation. Assessment of verticality in the upright position requires the vestibular and visual systems. Somatosensory input is required when the head or whole body is tilted, as with individuals with hemiparesis. Tilting of one’s body can make a vertical line look as if it were tilted to the opposite side. This is termed the Aubert Effect, or the “A” effect.[19] The “A” effect occurs when an individual is unable to maintain an upright symmetrical position. When this occurs the individual’s perception of verticality is skewed and this is seen when the individual leans in the direction that the line is tilted towards.[20] Brandt et al[21] reported that an individual utilizes information from the visual, proprioceptive and vestibular systems to interpret vertical.

In a study by Snowdon and Scott[18], where they compared individuals with CVA (n=12) to healthy individuals (n=9), perception of vertical was determined by showing them a line or rod that could be rotated within their frontal plane. The subject indicated when they thought the line was vertical and the average of 10 trials was then termed "subjective visual vertical". They found that subjects who had a CVA tilted their bodies in the same direction as the line and that the subjects who had a less accurate perception of vertical demonstrated increased upright postural deficits with the subjective visual vertical ($P < 0.001$).[18] Deviation of subjective visual vertical has been shown to occur in individuals following a CVA.[11] Brandt et al[21] showed that 23 out of 52 patients with a middle cerebral artery infarct had a subjective visual vertical that was tilted more than 2.5º, which could lead to balance and postural impairments; therefore putting them at a greater risk for falls.

Figueiro et al[15] performed a study to investigate the effectiveness of a novel self-illuminous light emitting diode (LED) night lighting system that provided linear spatial orientation cues plus low ambient illumination for increasing postural control in healthy adults. This device was a lighted frame that was constructed similar to a door frame that is lit with LED bulbs around it. Tests were performed with healthy seniors (n=16) and postural control was assessed using a standardized sit-to-stand (STS) test (EquiTest® System)[22] , as a measure of the individual's ability to transfer from STS. Sway velocity (SV) and left/right (L/R) weight symmetry were used to measure the person's ability to move from the sit position to the stand position because these measures are affected by the visual information presented in the study. SV documents control of the center of gravity over the base of support during the rising phase and for 5 seconds after coming to the standing position and is expressed in degrees per second. L/R symmetry measures the difference in the percentage of body weight on each foot while subjects are transferring from the sit position to the stand position during one trial.[15]

The study tested three separate conditions, 1) the lighted frame at midline, 2) the lighted frame tilted to the right, and 3) the light tilted to the left. During each of these separate conditions the background lights were off and only the lighted frame was on. Subjects completed three STS trials for each condition, in a randomized order. The results of the study found that there is an influence between the visual environments on postural orientation. When the door was tilted to the left, the healthy older adults leaned more to the left, and when the door was tilted to the right the same subjects leaned to the right.[15]

In a follow up study performed by Gras et al, 2008[23], researchers looked at the affects of the lighted tilted frame with individuals who have had a CVA (n=5). The subjects went through four different lighted frame trials. The trials consisted of the frame tilted to the involved side, the frame tilted to the uninvolved side, and two trials of the frame in midline. Three trials of STS were completed for each condition. Results showed that when the frame was in midline the percentage of weight bearing (% WB) on their uninvolved LE was 28.8%, when the frame was tilted toward their involved side the % WB on their involved side was 20%, and when tilted toward their involved side the % WB on their uninvolved LE was 35.6%.[23] These results again illustrate the strong reliance on the visual system in maintaining postural control for subjects who had a CVA.

Due to the results of these two studies using the lighted tilted frame, we wanted to determine if this system would be a valid instrument for use as an intervention with individuals who have had a CVA, resulting in hemiparesis that causes them to weight bear asymmetrically.

The purpose of this single subject design is to investigate the effect of a lighted tilted frame on symmetrical weight bearing in two individuals who have had a CVA.

It was hypothesized that when the lighted frame was tilted towards the subjects' involved side, it would prompt the subjects to put more weight on their involved side creating a more symmetrical stance. By improving symmetrical weight bearing, we hypothesized that the subjects would have improved scores on the Berg Balance Scale (BBS), Fugl-Myer Assessment (FMA) and increased gait velocity and stride length.

Methods

The study took place in the Physical Therapy Department at The Sage Colleges in Troy, New York with the approval of Sage's Institutional Review Board

Subjects

Two subjects were recruited from a previous study "The Use of a Lighted Tilted Frame to Assist in Midline Orientation for Individuals Who Had a Stroke", by Gras, Flatebo and Knapp[23] as a convenient sample. The two subjects who were chosen from the above mentioned article for this study because they had the most involved asymmetrical stance, which is an increase in weight-bearing on the uninvolved LE in standing. Subject 1 is a 58 year old male who has right hemiparesis as the result of a left CVA which occurred in 2003. After conducting the research on Subject 1, it was decided to add a second subject to determine if there is a difference between individuals with a right and left CVA. Subject 2 is a 58 year old female with left hemiparesis as the result of a right CVA which occurred in 2003. The subjects were chosen with the following inclusion criteria: presence of a CVA greater than one year, ability to transition from STS independently, and ability to understand simple instructions. The exclusion criteria included: absence of Pusher's syndrome, or any other neurological condition that could interfere with standing balance, and absence of orthostatic hypotension. Upon arrival subjects signed an informed consent, approved by Sage's Institutional Review Board prior to participating.

Examination

At the initial visit a physical therapy examination was performed on the subjects consisting of a history, review of systems (blood pressure, gross strength as measured by manual muscle testing, goniometric measurements of range of motion), vision as measured with the Snellen chart and visual acuity testing[8], and tests for balance and gait. The balance examination was performed using the BBS. The Sit to Stand (STS) Test on the EquiTest® System was used to assess the subjects' percent weight bearing (% WB) between both LE's during the process of rising from the chair. The gait examination included velocity and stride length utilizing the GAITRite Mat system. The FMA and Modified Ashworth Scale (MAS) were used to assess impairment. These tests were selected because they are often used for identifying impairments in patients who have had a CVA.

The BBS has been found to be a psychometrically sound measure for balance impairment in patients following CVA. It is responsive to change and is often useful for measuring outcomes of post CVA rehabilitation interventions.[24] The BBS has an inter-rater reliability (intraclass correlation coefficients [ICC]=.95-.98), intra-rater reliability (ICC=.97), and test-re-test reliability (ICC=.98).[24]

Hemiparetic gait characteristics include slow walking speed and asymmetrical step length which leads to increased energy expenditure and increased risk for falls.[6]

In a single subject case report by McDonough et al[25] looking at the concurrent validity of the GAITRite Mat, they reported correlations for the GAITRite for right step length, ICC=.97, and left step length, ICC=.99, and correlation for walking speed measures are ICC=.96.[25] The subjects were instructed to begin walking at their normal pace 2 meters before the mat to ensure that they had reached their self selected pace and 2 meters after the mat to account for deceleration. Subject 2 requires the use of a straight cane and a knee-ankle-foot orhthosis (KAFO) for ambulation and was allowed to use the device during the GAITRite measurements as the program accounts for this extraneous data.

The FMA was chosen because it is a tool that is specific for individuals who have had a CVA and is a performance-based impairment index. The FMA was used to test reflex activity in the LE, LE range of motion in supine, standing and sitting, coordination of the LE's, and sensation of upper and lower extremities in individuals who have had a CVA resulting in hemiparesis.[26] FMA inter-rater reliability is ICC=.96, reliability coefficients for pain, ICC=.61, and upper extremity items, ICC=.97. [27] Intra-rater reliability for the Fugl-Myer is ICC=.86-.99.[28]

The Modified Ashworth Scale (MAS) was used to measure tone in the LE's. The scale ranges from 0-4 with the higher numbers corresponding to increased tone. MAS intra-rater reliability is ICC=.567 for the lower extremity.[29]

The ability to transfer from STS is important for performing ADL's independently and requires more LE strength than walking or climbing stairs. Lomagio and Eng[30] looked at the relationship between weight-bearing symmetry and STS performance in individuals with chronic CVA (n=22). They found that greater weight-bearing symmetry related to faster STS performance (r=0.565). The results of the study by Lomagio and Eng[30] show that the STS test may be useful in determining an individuals' functional level. The STS test measures % WB between sides and measures the right/left symmetry during the first 5 seconds of standing, with the objective to decrease the % WB on the uninvolved lower extremity so that weight-bearing is more symmetrical.

Upon arrival, the subject first performed the STS prior to the standing intervention and again after the intervention. This was done for each phase in order to determine if the intervention had an effect on symmetrical weight-bearing, with each subject. A screen was placed between the examiner and the subject in order to reduce visual distractions, and the subject was instructed to look straight ahead. The subjects were seated on blocks on a long force plate (EquiTest® System) which examines mediolateral sway, and they were instructed to stand after the examiner said "GO" and to remain standing until instructed to sit back down. This was repeated 3 times for each trial. The subject was guarded while performing the STS by one of the researchers who stood behind them.

Intervention

The study design was a single subject design with two subjects, including an A, B, and C phase. The interventions were performed one subject at a time. Data collection for Subject 1 occurred between October 2007 through December 2007, and for Subject 2 from January 2008 through March 2008. During the A, B, and C phase a standard armless chair was placed 60 inches from the wall and marked with a piece of tape. The distance of 60 inches was used since it was the same distance used in the study by Gras et al. The subject was seated in the chair and instructed to stand when ready, at which time a stop watch was used to time the subject for a duration of 15 minutes. The subject was guarded by a licensed physical therapist or physical therapy student who was directly supervised by the licensed physical therapist standing outside of the subjects' periphery. Phase A (control phase) consisted of the subject standing in front of a white wall and instructed that they could speak, but that in order to eliminate distraction the researchers would not speak and this was reinforced during all phases. During Phase B (intervention phase) the lighted frame, which is a frame that was constructed similar to a door frame that is lit with LED bulbs around it was tilted toward their involved side, and during Phase C (intervention phase) toward their uninvolved side. Phase C was added after the researchers noticed a tendency to lean in the opposite direction of the tilt while guarding the subject. A 4.3º tilt was achieved using a 9.5 cm wedge placed under the frame. The degree of tilt was chosen as it was previously used in the study by Figueiro et al.[15]

The following tests and measures were used at the beginning and end of every phase: BBS and gait velocity and stride length using the GAITRite Mat. The MAS and the FMA were performed at baseline, prior to beginning Phase A and at the end of Phase C. Each phase consisted of 6 sessions; however, subject 1 had 7 sessions during Phase A and 9 sessions during Phase C due to fatigue from traveling. Subject 2 also had added sessions, with a total of 8 sessions during Phase B, secondary to complications with her KAFO which were resolved prior to beginning Phase C. Postural assessment was performed during each session through visual observation.

Data Analysis

Descriptive/qualitative postural assessment was performed through researcher observation of the subject's static standing posture during each standing intervention period of the session.

Statistical analysis was performed on the % WB data during the STS test using a split-middle line[31], two band width method, and mean level. The data was collected using the EquiTest® System measuring the % WB. The data was analyzed using the STS test before and after the standing intervention of each session. The pre standing data and post standing data of Phase B and Phase C was compared to the pre standing and post standing data of Phase A to determine if the tilt of the lighted frame caused a true change.

The split-middle line is used to compare the trend of data between 2 adjacent phases. Trend refers to the direction of change within a phase. When there is a change in trend from baseline to the intervention phase it may be indicative of a true change caused by the intervention.[31] To determine the trend within each phase a celeration line is drawn for the pre and post Phase A and the split-middle line is extended to the pre and post B and C Phase (intervention phases). If there is no difference between the phases, then the split-middle line for baseline data should also be the spit-middle line for the intervention phase. Therefore, 50% of the data in the intervention phase should fall on or above that line, and 50% should fall on or below it. If the intervention made a change then more than 50% of the data should fall on, above or below the spilt-middle line.[31]

The two standard deviation band width method involves measuring a change within the baseline phase by calculating the mean and standard deviation within that phase. A line was drawn to represent the mean during the baseline phase (A phase) and was extended on the graph into the B and C phases. Then the two standard deviation away from the mean was calculated and lines were drawn to represent two standard deviations above and below the mean and extended into the B and C phases. If at least two consecutive data points in the intervention phases extend above or below the two standard band width, then it is said to be significant.[31]

A change in the level refers to the shift of the subject's performance at the point of the intervention.[31] The mean level was calculated for each phase, and a line was drawn across for each of the phases in the graph. If there is a difference between the mean lines of one phase compared to the other phases, a change in level is shown.

Descriptive analysis comparing the change in scores on the BBS, FMA and GAITRite measurements following each phase was documented using charts. This was done to determine the effects of the tilted frame.

Results

Subject 1

Subject 1 is 5 years post CVA, which resulted in right hemiparesis. Static standing posture revealed right shoulder depression, cervical side bend to the right with head rotation to the left, right genu recurvatum, and bilateral hip external rotation. Subject 1's standing posture did not change throughout the study. Visual field was tested and subject 1 had no deficits.[8] The Snellen test was performed and revealed 20/30 vision for the left and right eye when tested individually, and 20/20 when tested together. FMA scores were 128/226 at baseline and 131/226 upon completion of the study. BBS scores were 41/56 at baseline and 46/56 upon completion of the study. Scores for standing unsupported with feet together remained the same from baseline through the end of Phase B, and increased at the end of Phase C by 3 points. Scores for turning to look behind over left and right shoulders increased by 1 point from baseline for all phases. Scores for standing unsupported, 1 foot in front, was 0 at baseline and increased by 1 upon completion of the study. Gait velocity was 66.4 cm/s at baseline and 70.7 cm/s upon completion of the study. Stride length measures decreased from baseline to completion of the study for bilateral LE's (Table 1).

When comparing pre-intervention A to pre-intervention B and pre-intervention A to pre-intervention C subject 1 showed an increase in mean % WB (Figure 1), and a decelerating trend line indicating the subject was putting more weight on the uninvolved side (Figures 2 and 3). The two standard deviation band method was significant when comparing pre-intervention A to pre-intervention B, indicating the subject was putting more weight on the uninvolved side (Figure 4). The two standard deviation band method was not significant during any other phase.

When comparing post-intervention A to post-intervention B subject 1 showed an increase in % WB on the uninvolved side, however; when comparing post-intervention A to post-intervention C the % WB decreased indicating movement toward a more symmetrical stance (Figure 5). When comparing the post-intervention A to post-intervention B, and post-intervention A to post-intervention C, there was an accelerating trend line, indicating the subject was putting more weight on the involved side (Figure 6 and 7).

Subject 2

Subject 2 is 5 years post CVA, which resulted in left hemiparesis. Her static standing posture reveals a depressed left shoulder, posterior pelvic tilt, hands clasped in front of her body, left scapular protraction and abduction. Subject 2's standing posture did not change throughout the study. Subject 2 wears a KAFO on her left LE. Visual field was tested and subject 2 had no deficits.[8] The Snellen test was performed with subject 2 wearing glasses, and the results were 20/13 for the right, 20/50 for the left, and 20/13 when tested together. FMA scores were 129/226 at baseline, and 147/226 upon completion of the study. Joint range of motion, sensation and balance increased by 3 points from baseline to completion of the study. The LE score increased by 4, and the UE increased by 5 from baseline to completion of the study. BBS scores were 43/56 at baseline, decreased by 1 point following Phase A, and increased by 1 point following Phase B and C (Table 2). Gait velocity and bilateral stride length measures increased from baseline to completion of the study (Table 2).

When comparing pre-intervention A to pre-intervention B and pre-intervention A to pre-intervention C, Subject 2 showed a decrease in mean % WB for the STS test (Figure 8) and an accelerating trend line indicating the subject was putting more weight on the involved side (Figure 9 and 10).

When comparing post-intervention A to post-intervention B subject 2 showed an increase in mean % WB on the uninvolved side, however; when comparing post-intervention A to post-intervention C the mean % WB decreased indicating movement towards a more symmetrical stance following Phase C (Figure 11).

When comparing post-intervention A to post-intervention B and post-intervention A to post-intervention C, there was an accelerating trend line (Figure 12 and 13) indicating the subject was putting more weight on the involved side and moving towards a more symmetrical stance.

Discussion

The study was performed with 2 subjects who have chronic hemiparesis. The purpose of the study was to find out if repeated exposure to a lighted tilted frame could bring the subjects back to midline and a more symmetrical stance. It was hypothesized that when the lighted frame was tilted towards the subjects' involved side, it would prompt the subjects to put more weight on their involved side creating a more symmetrical stance. This hypothesis was based on the findings of Gras, Flatebo, and Knapp[23], which found that when performing the STS with the frame tilted towards the involved side, the subjects leaned towards the involved side, therefore; creating a more symmetrical stance.

When comparing both subjects, the results of our study showed that during Phase B, when the frame was tilted toward the involved side, both subjects demonstrated an increase in mean % WB on the uninvolved side compared to Phase A, indicating that they may have been attempting to right themselves by overcorrecting for the tilt. Three sessions were also added for Subject 1, during Phase C, when the frame was tilted toward the uninvolved side, after reports of fatigue during several sessions. During Phase B, Subject 2 reported that her KAFO was broken, which may account for the increase in mean % WB on the uninvolved side. We attempted to account for the broken KAFO by adding 3 additional sessions to Phase B. Following Phase C, Subject 1 showed an increase in his BBS score from 41/56 at baseline to 46/56 upon completion of the study. A score less than 45 indicate that an individual is at a high risk for falls[8]; therefore, Subject 1 is no longer in the high risk category for falls which may have been the result of the intervention performed during the study. Blum[24] reported that the BBS is responsive to change and is useful in measuring various outcomes of CVA rehabilitation interventions. Stevensen[32] reported that a change of ± 6 BBS points is necessary to be 90% confident of a genuine change. Subject 1 had a 5 point change. During Phase C, both subjects, had a decrease in mean % WB compared to Phase B, however; subject 1 did not return to the results seen during Phase A, where as subject 2 decreased her mean % WB by 4.83% from Phase A. It appears that when the frame was tilted towards the subjects uninvolved side there was a more symmetrical stance. These findings are not in agreement with the findings of Gras et al, 2008[23], which showed that when the frame was tilted toward the involved side there was a more symmetrical stance.

Figuero et al[15] found that initially there is a reliance on visual cues and then after periods of standing there is a greater reliance on proprioceptive and vestibular input. Bonan et al[17] reported that individuals with left CVA rely on vestibular input and individuals with right CVA rely more on vision. Subject 1's % WB varied session to session compared to Subject 2 (Appendix B) during all phases, showing no consistency. The findings by Figuero et al[15] and Bonan et al[17] may explain factors which contributed to the variability of Subject 1. Standing for longer periods of time may have caused Subject 1 to rely more on proprioceptive and vestibular input than on the visual input from the lighted tilted frame. The fact that Subject 1 had a left CVA may also indicate that he does not have a strong reliance on visual input. Subject 1 demonstrated decreased proprioception as seen by his FMA scores which were 0-1 for the involved lower extremity. Many patients with hemiplegia rely more on visual input according to Bonan et al[17], and this may be more common with those who have had a right CVA. This may be why Subject 2, who had a right CVA, did much better with this intervention than Subject 1. These findings suggest that it is important to assess the individual's specific impairments prior to beginning rehabilitation to determine if they rely more on vision or proprioceptive and vestibular input and tailor the interventions to that need. Research has found that visual feedback has been effective in increasing and maintaining symmetrical weightbearing.[5] Our study showed that the use of a lighted tilted frame may be a possible intervention to use with those who rely more on visual input.

When considering the variability seen with Subject 1, it should be noted that individuals who have hemiparesis are less apt to put weight through their involved side due to fear of instability when going from sit to stand. When given a choice those with hemiparesis may not put as much weight through their involved side as they are capable of due to fear of instability and weakness of the involved side.[33] The symmetry seen while the subjects were performing the standing intervention may not carry over when the subjects are moved to the EquiTest® to perform the STS test to measure their % WB. The STS test may not have shown the symmetry resulting from the standing intervention because the subjects may not have been putting as much weight as they are capable of on their involved side. Even with symmetrical foot placement during STS, individuals may have asymmetrical knee effort, therefore; they use the uninvolved side, which is stronger, to propel themselves into standing. [33] This may have been reflected in the results seen during the STS portion of the study. It may be useful for future studies to use a device that would measure the subject's % WB while standing in front of the lighted tilted frame to see if the intervention was causing a true change in the subjects' symmetrical stance.

Gait parameters for both subjects were compared using the GAITRite mat. Subject 1 had increased velocity following Phase B and Phase C, and Subject 2 had increase gait velocity and bilateral stride length following all phases compared to baseline. Yavuzer et al[6] reported that individuals with hemiparesis often have slow and asymmetrical gait patterns, both of which are associated with an increase risk of falls. Slower walking speeds and shorter stride length have been attributed to increased risk for falls in elderly subjects as well.[34] Falls occur while individuals are walking and poor gait performance is associated with falling, so the increase shown by both subjects in our study, may be an indicator that they have decreased their risk of falling. It has also been shown that when individuals who have had a CVA resulting in hemiparesis, have a difference in % WB less than or equal to 30% they have better gait performance.[4] Both subjects had increases in gait velocity and their mean % WB was below 30% following all Phases, with the exception of post-intervention Phase B for Subject 2 which was 31.13% on the uninvolved LE.

Lee et al[35] reported that during STS those with hemiparesis who put more weight through their uninvolved side showed lower mobility scores on the Functional Independence Measure; therefore, individuals with symmetrical weight bearing may become more functional. Upon completion of the study, Subject 1 reported that he was able to stand in the shower with more ease. This may be attributed to his increase scores on the BBS, as well as the movement toward a more symmetrical stance following Phase C. Subject 2 reported greater ease with getting up and down in the pews at church, which may be attributed to the more symmetrical stance following Phase C. Subject 1 showed a decrease in %WB 4 out of 7 times during the pre-intervention of Phase A (Figure 14), and Subject 2 showed a decrease 3 out of 6 times during the pre-intervention of Phase A (Figure 15) and 3 out of 8 times during Phase B (Figure 16)and 2 out of 6 times during Phase C (Figure 17). These may have been due to carryover effects. Also the fact that both subjects experienced subjective improvements post research demonstrates possible carryover effects as well.

When comparing the data analysis with the mean % WB and split-middle lines, the same data can be viewed differently. Means and split-middle lines are visual analysis and often used in single subject designs, because with basic information researchers are able to accurately describe outcomes.[31] Using the mean % WB comparing post-intervention Phase A to Phases B and C, we see that Subject 1 showed an increase mean % WB in Phase B and decrease in Phase C. When looking at the same data with the split-middle line, Subject 1 showed an accelerating trend following both Phase B and Phase C. The reasoning is that even though the mean % WB may show that the subject is putting more weight on the uninvolved side, the data may have been skewed by a couple of sessions when the subject was reporting fatigue and there was variability in his scores. Also, the accelerating trend lines are useful as an estimate of the trend, but the interpretation may be limited because it is not affected by extreme scores.[31]

A strength of this study is that both subjects experienced CVA's in the same year. Our study wanted to show the effects of visual input alone as an intervention for individuals who have had a CVA for at least 6 months. We selected subjects who have chronic CVA's to show if any changes in %WB were due to our intervention and not due to spontaneous recovery or neuroplasticity. Studies have shown that the most significant changes in motor function occur during the first 3 months of recovery.[36] However Verheyden et al[36], and Schaechter[37] et al showed that by using motor skills that challenge the subjects we can still see motor recovery 6 months after a CVA. Another strength was that all three researchers performed the outcome measures together and discussed the results which increase the reliability of the results of the outcome measures.

Limitations of the study include; using the STS before and after standing as opposed to using it while standing to see when the subjects were most symmetrical. Another limitation was that the subjects' subjective visual vertical was not assessed prior to the study.

Bonan et al[38] performed a study of individuals with hemiplegia (n=30) and found that subjective visual vertical misperception is directly related to poor balance after CVA (P<.001). A test of subjective visual vertical may be a simple tool for adapting rehabilitation programs for individuals with impaired perception of verticality.[38] Due to the small sample size and that this was a convenience sample; this decreases the power of the study. We did not exclude those with musculoskeletal impairments which may have affected the subjects' performance during the standing intervention as both subjects had knee osteoarthritis. The study also included one male subject and one female subject that had different lesion sites which do not allow the results to be generalizable to all individuals who have had a CVA resulting in hemiparesis.

Further research is needed to determine therapeutic parameters and should incorporate an ABACA design in order to determine which phase showed the most improvement. It is also suggested that the Clinical Test for Sensory Interaction in Balance (CTSIB) be used prior to the intervention so that can determine which system the subject relies on for balance. The time of the standing intervention may need to be on a progressive scale as 15 minutes may have initially been too long for the subjects. The lighted tilted frame may also be used during the acute phase of rehabilitation as most of the recovery occurs in the first one week to one month post CVA.[36] The lighted tilted frame can be used in the acute setting or in the outpatient setting, and should be in a room where there are no auditory or visual distractions.

Conclusion

In conclusion this is the first study to look at the use of a lighted tilted frame as an intervention for individuals who have had a CVA resulting in hemiparesis. The results of our study may be useful for clinicians in developing an intervention for asymmetrical weight bearing with the use of visual feedback. Further research is needed to determine the appropriate parameters to use with the lighted tilted frame as an intervention to promote symmetrical weight bearing in those who have had a CVA resulting in hemiparesis.

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Table 1: Descriptive Analysis of Outcome Measures (Subject 1)

	Baseline	Post Phase A	Post Phase B	Post Phase C
Velocity (cm/s)	66.64	57.50	78.50	70.70
Stride Length (cm) Left	84.69	70.94	85.88	81.76
Stride Length (cm) Right	85.89	73.30	84.58	80.09
Berg Balance Scale	41/56	43/56	42/56	46/56

Table 2: Descriptive Analysis of Outcome Measures (Subject 2)

	Baseline	Post Phase A	Post Phase B	Post Phase C
Velocity (cm/s)	46.40	49.30	50.30	51.30
Stride Length (cm) Left	86.87	82.27	84.69	96.73
Stride Length (cm) Right	93.13	83.07	88.62	97.81
Berg Balance Scale	43/56	42/56	44/56	44/56

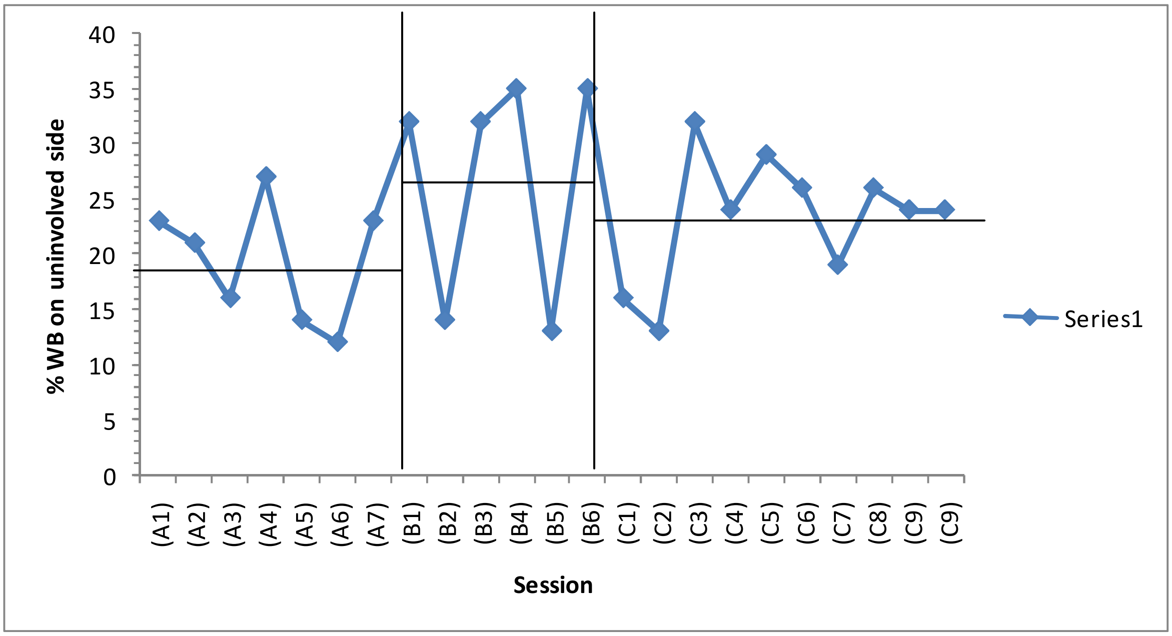

Figure 1: Mean % WB Pre Intervention (Subject 1)

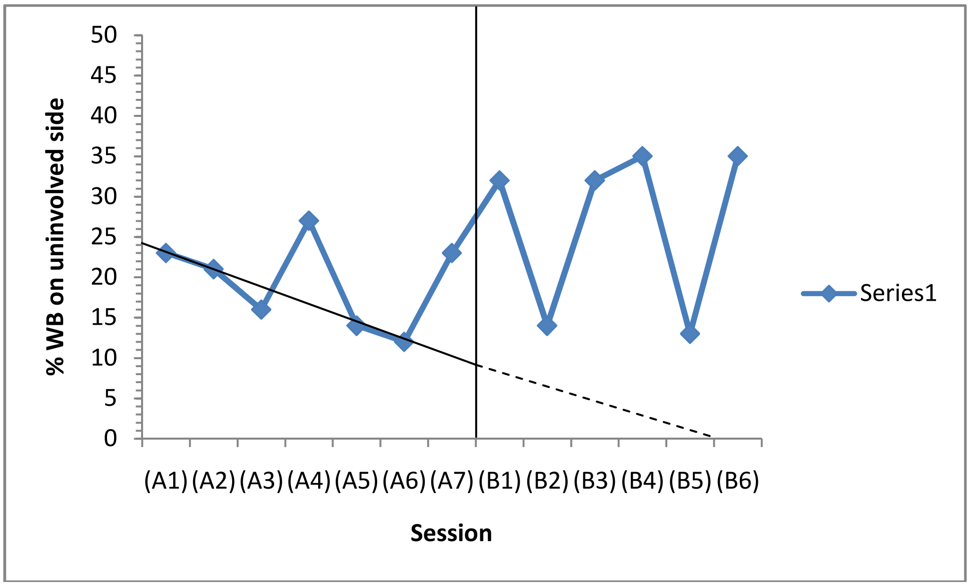

Figure 2: Split Middle Pre Intervention A vs. B Phase (Subject 1)

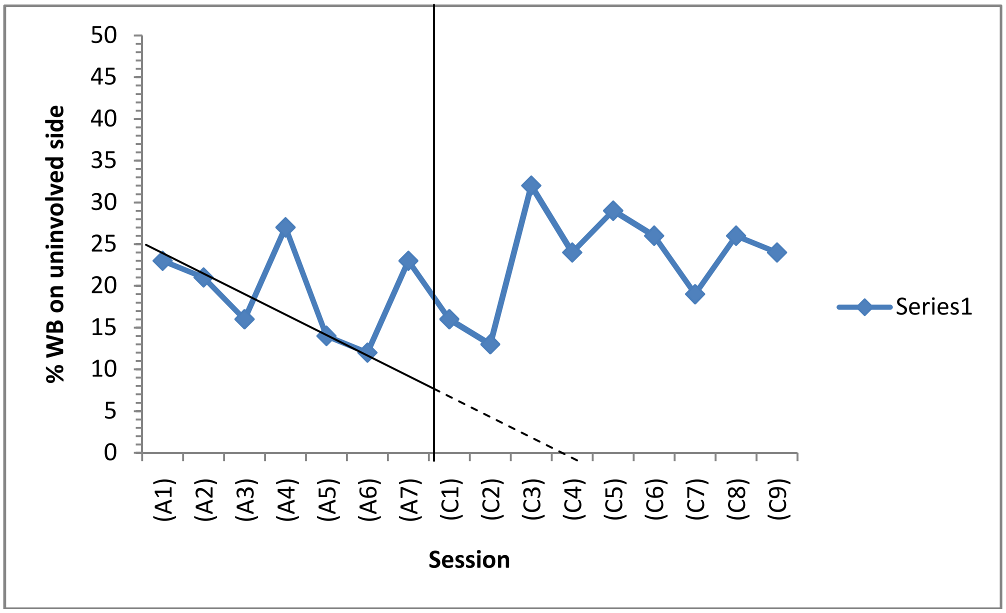

Figure 3: Split Middle Pre Intervention A vs. C Phase (Subject 1)

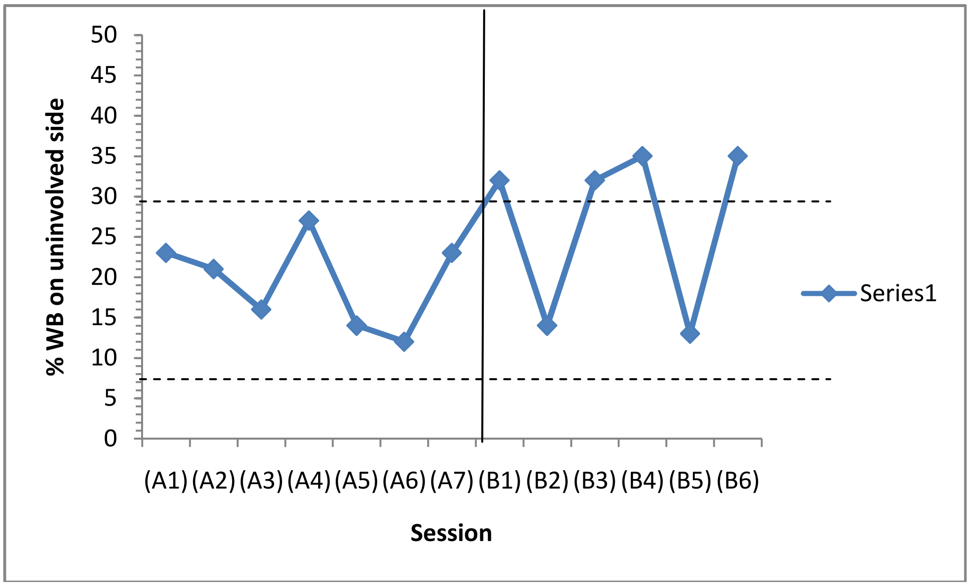

Figure 4: Two Standard Deviation Band Width Method; Pre Intervention A vs. B Phase (Subject 1)

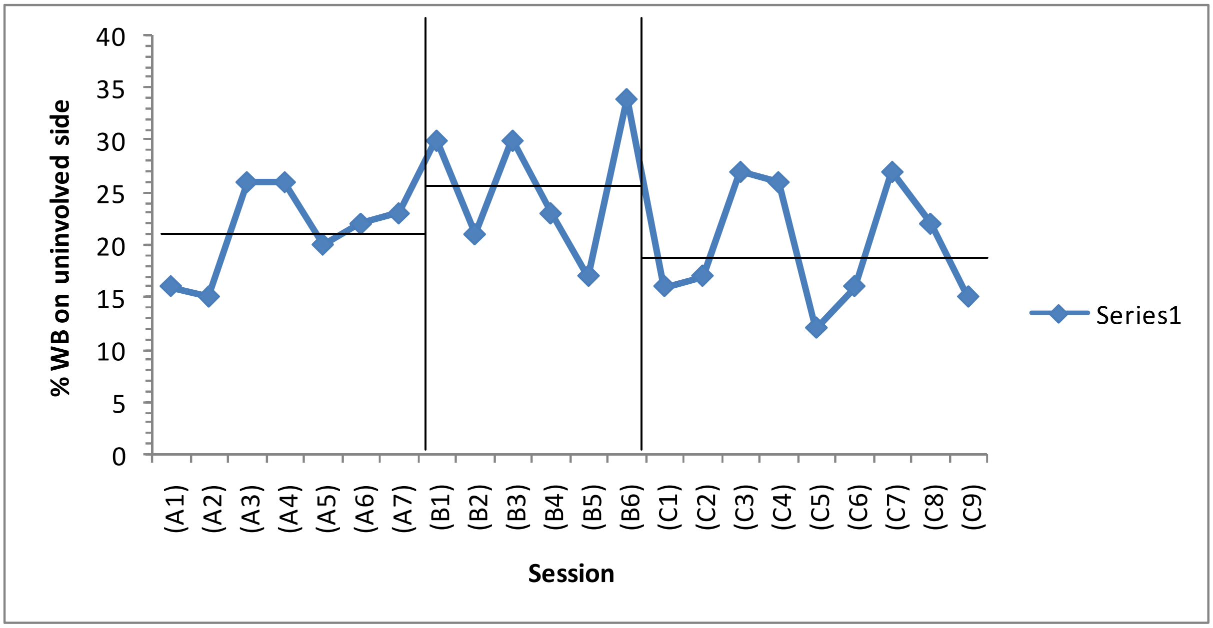

Figure 5: Mean % WB Post Intervention (Subject 1)

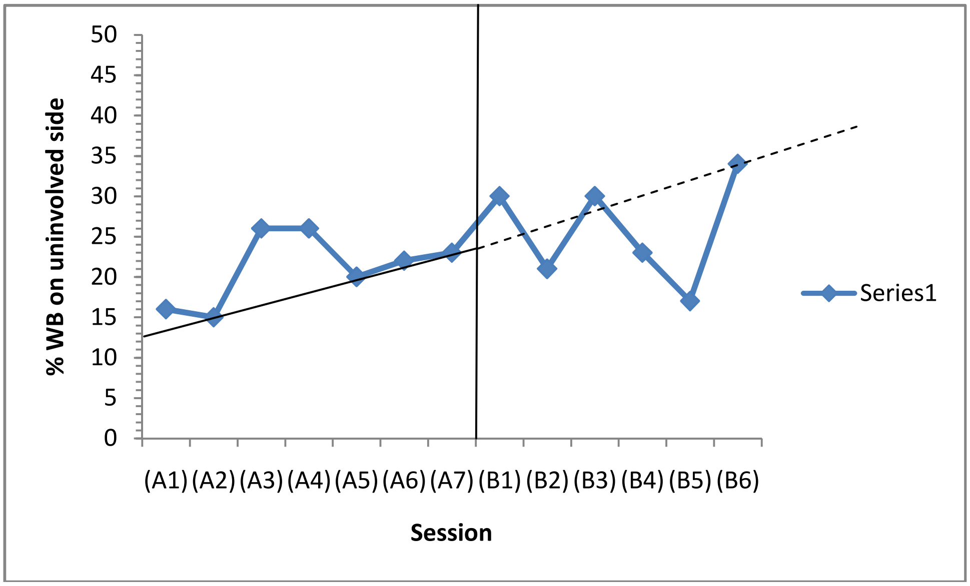

Figure 6: Split Middle Post Intervention A vs. B Phase (Subject 1)

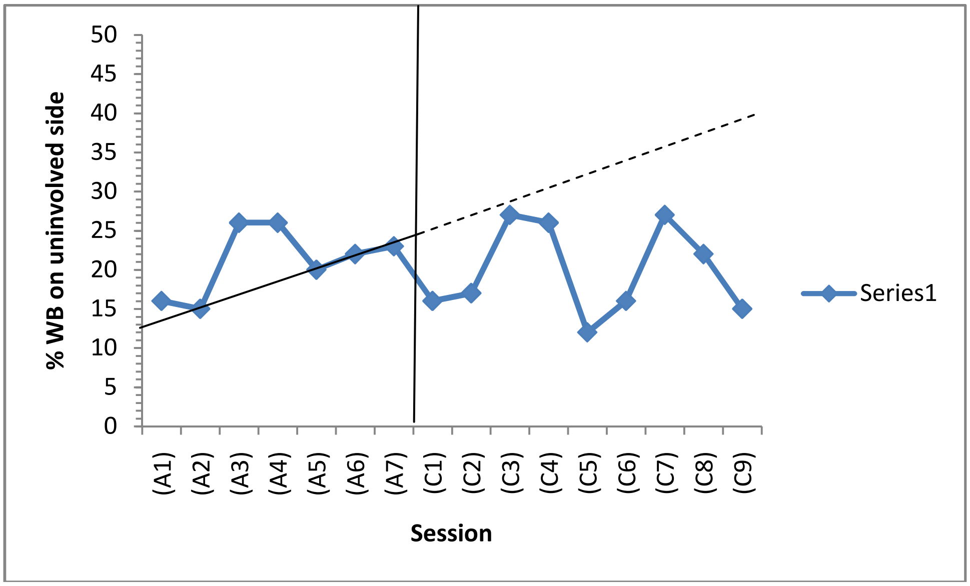

Figure 7: Split Middle Post Intervention A vs. C Phase (Subject 1)

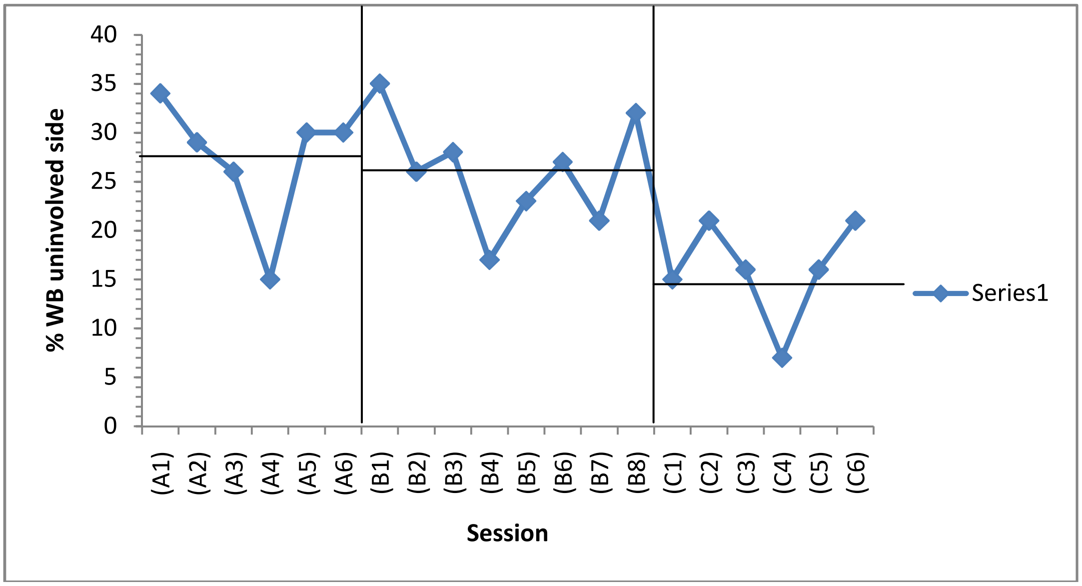

Figure 8: Mean % WB Pre Intervention (Subject 2)

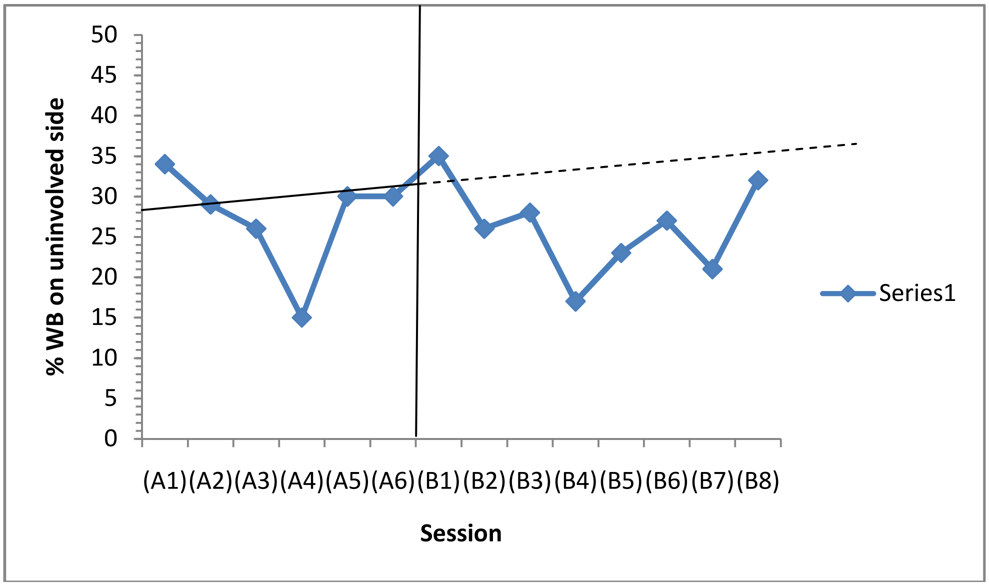

Figure 9: Split Middle Pre Intervention A vs. B Phase (Subject 2)

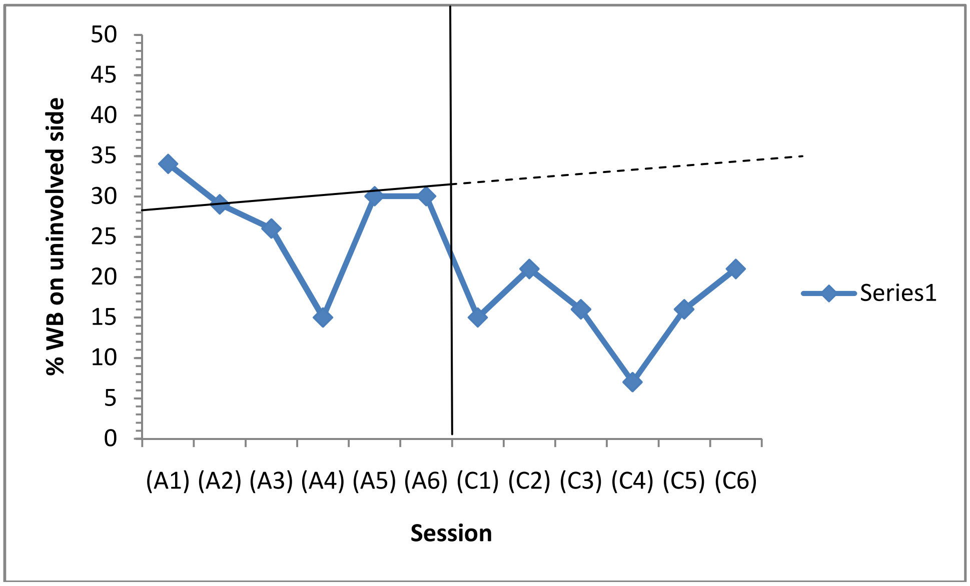

Figure 10: Split Middle Pre Intervention A vs. C Phase (Subject 2)

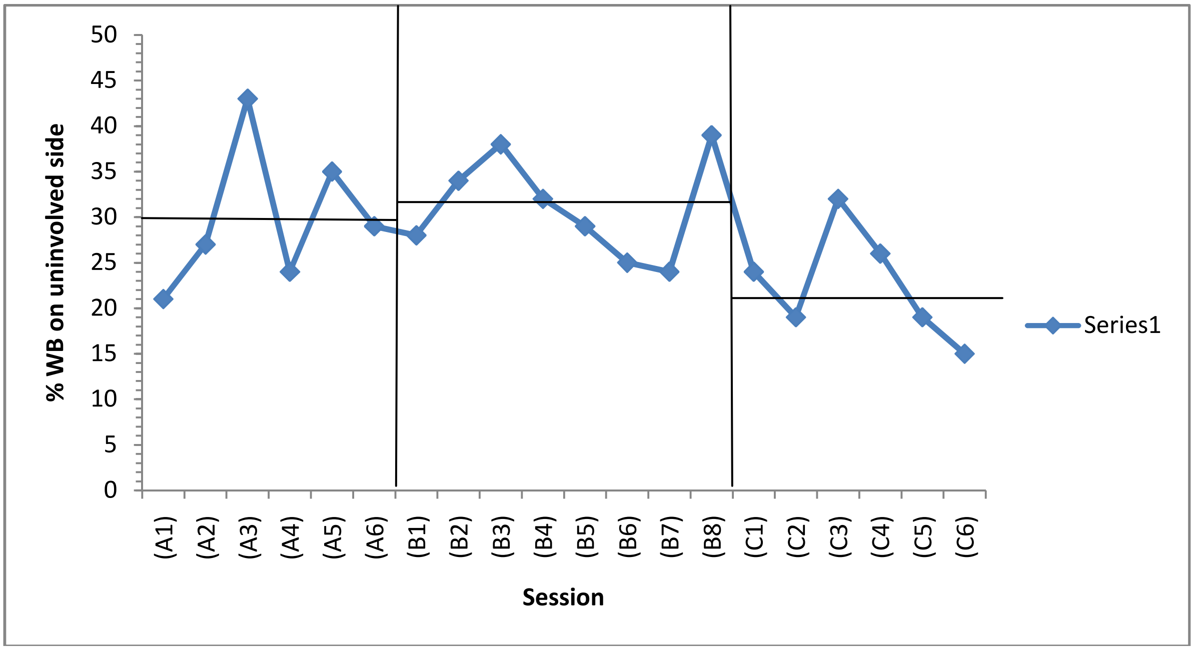

Figure 11: Mean % WB Post Intervention (Subject 2)

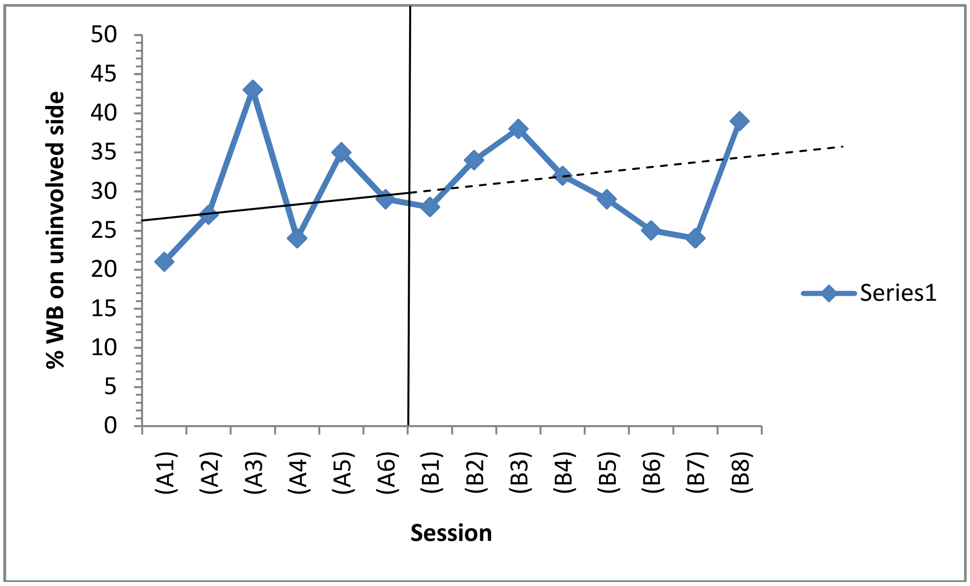

Figure 12: Split Middle Post Intervention A vs. B Phase (Subject 2)

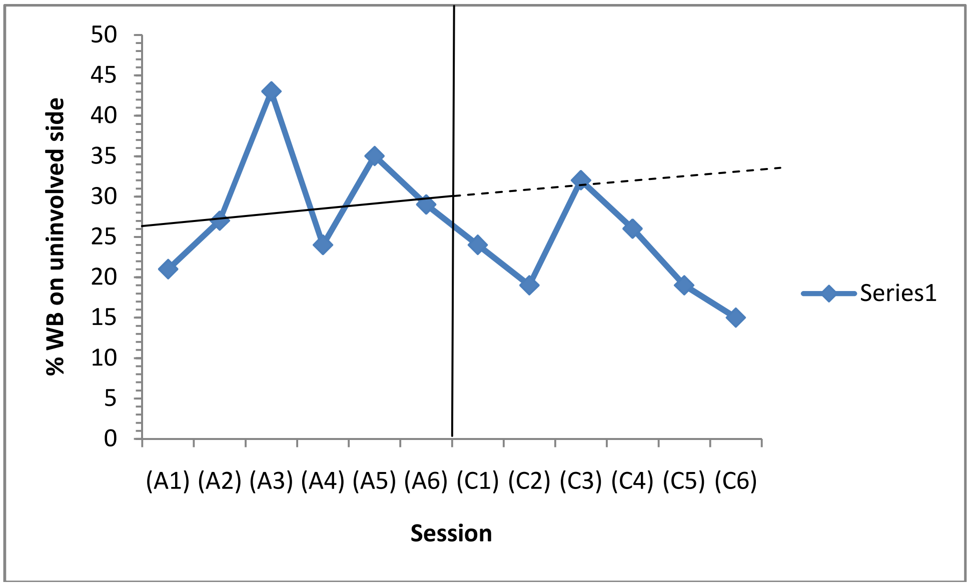

Figure 13: Split Middle Post Intervention A vs. C Phase (Subject 2)

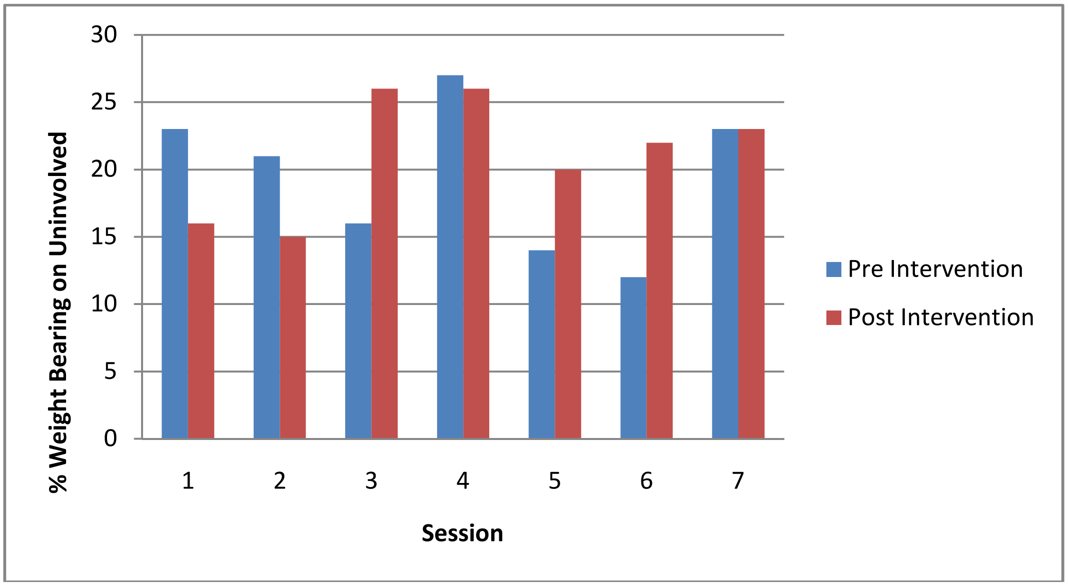

Figure 14: Pre Intervention vs. Post Intervention Phase A (Subject 1)

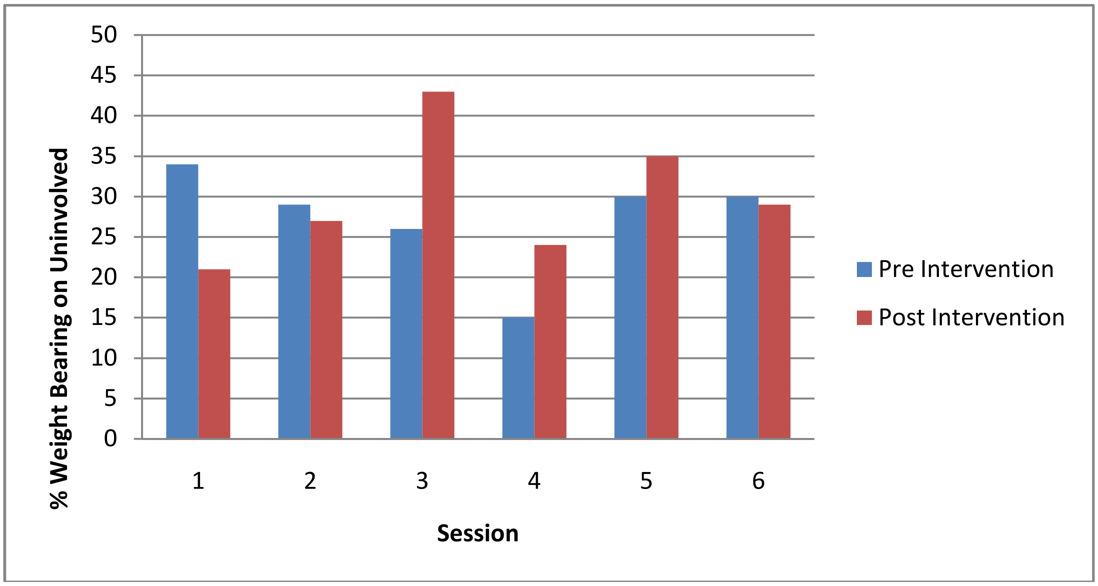

Figure 15: Pre Intervention vs. Post Intervention Phase A (Subject 2)

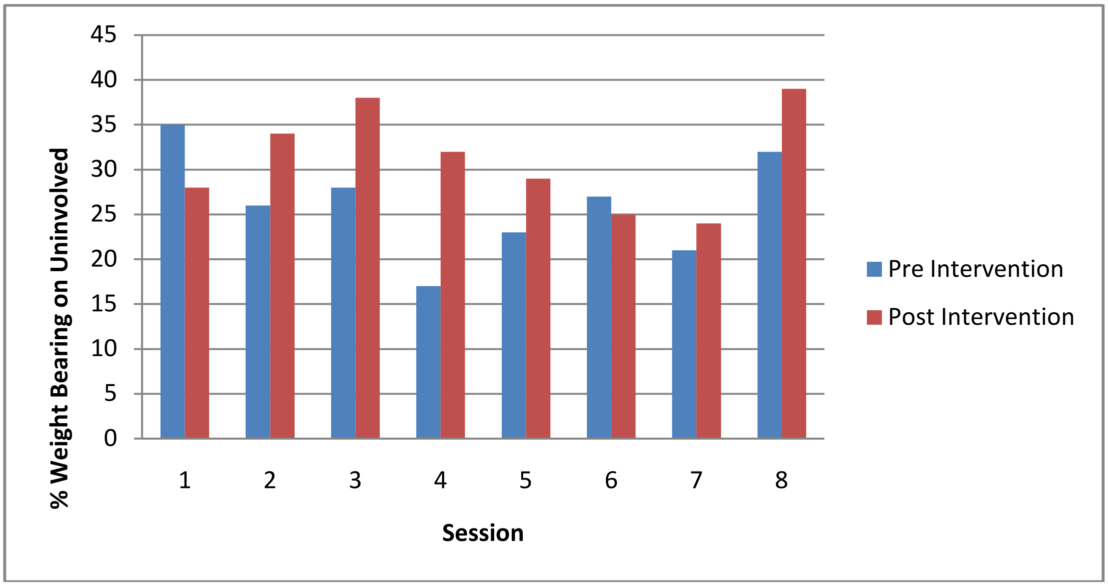

Figure 16: Pre Intervention vs. Post Intervention Phase B (Subject 2)

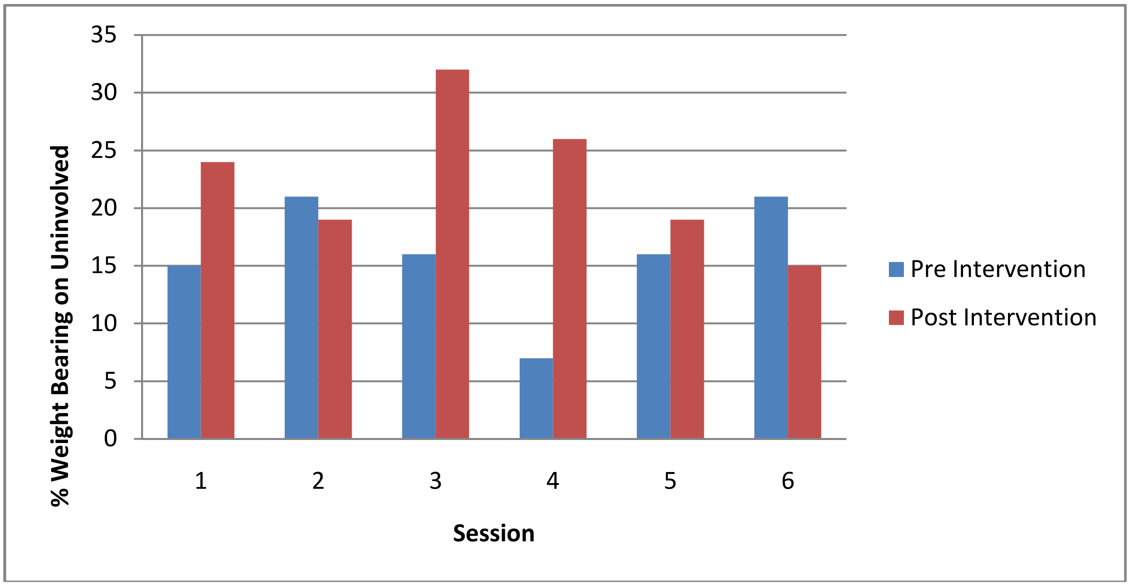

Figure 17: Pre Intervention vs. Post Intervention Phase C (Subject 2)