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## USE OF A VIDEO GAME BASED BALANCE TRAINING INTERVENTION ON THE BALANCE AND FUNCTION OF CHILDREN WITH DEVELOPMENTAL DISABILITIES

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Gina C. Siconolfi-Morris, Student

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Dr. Anne Olson, Director of Graduate Studies

USE OF A VIDEO GAME BASED BALANCE TRAINING INTERVENTION ON  
THE BALANCE AND FUNCTION OF  
CHILDREN WITH DEVELOPMENTAL DISABILITIES

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DISSERTATION

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A dissertation submitted in partial fulfillment of the  
requirements for the degree of Doctor of Philosophy in the  
College of Health Sciences at the University of Kentucky

By

Gina Cecilia Siconolfi-Morris

Lexington, Kentucky

Co-Directors: Dr. Susan K. Effgen, Professor of Physical Therapy  
and Dr. Carl G. Mattacola, Associate Professor of Athletic Training

Lexington, Kentucky

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## ABSTRACT OF DISSERTATION

### USE OF A VIDEO GAME BASED BALANCE TRAINING INTERVENTION ON THE BALANCE AND FUNCTION OF CHILDREN WITH DEVELOPMENTAL DISABILITIES

Many children with developmental disabilities (DD) have physical impairments and limitations in their participation. Rehabilitation research often focuses on either physical impairments or participation restrictions, when both need to be investigated.

The purposes of these two studies were to evaluate an at home therapist directed video game balance training intervention on balance, gait velocity (GV), hip strength and activities of children with DD. The pilot study was a single-subject non-concurrent multiple baseline design. Balance measures included: weight bearing symmetry; center of pressure area and velocity; time to boundary mean minima and standard deviation; and timed up and go. The participant's enjoyment and perceived difficulty was also explored. Five children (7 to 10 years) with cerebral palsy (CP) participated in a 6 week, 30 minute intervention 3 times per week, with four preselected balance games. Minimal improvements were found in balance, GV, and hip strength, and participants reported the intervention enjoyable and challenging. Three of five participants had significant increases in activities, as measured by the Activities Scale for Kids (ASK).

The second study expanded on pilot study results and included 5 children (5 to 10 years) with different diagnoses. Another non-concurrent multiple baseline design was utilized, and the same measures of balance were used except single leg stance time was substituted for timed up and go. No changes were made to the intensity of intervention, but two games were added to the repertoire. There were minimal changes in balance and hip strength; and no changes were found in the ASK. A majority of participants increased GV, and reported the intervention was enjoyable and challenging.

Positive changes were found in the combined results for: center of pressure area with eyes open and closed; time to boundary mean minima with eyes closed in the anterior-posterior direction; and GV. These studies suggest this intervention was insufficient to make improvements in the majority of balance measurements and hip strength for children with DD. Increased activities in children with CP were found in the pilot study. These results suggest video game balance training alone for children with DD was insufficient to demonstrate clinically meaningful change.

KEYWORDS: Balance, Developmental Disabilities, Gait Velocity,  
Hip Strength, Activities and Participation

Gina Cecilia Siconolfi-Morris

July 2, 2012

USE OF A VIDEO GAME BASED BALANCE TRAINING INTERVENTION ON  
THE BALANCE AND FUNCTION OF  
CHILDREN WITH DEVELOPMENTAL DISABILITIES

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## **Chapter One: Introduction**

### **Background**

Rehabilitation professionals should employ evidence-based interventions during service delivery. However, there is a limited body of literature to support many interventions utilized by rehabilitation professionals in the clinic and prescribed for use at home. Home-based interventions are important for pediatric clinicians and practice because in many states there is a significant lack of pediatric therapists (Effgen, Myers, & Myers, 2007) and decreased funding for service delivery. With fewer therapists and decreased funding available to address the needs of children with disabilities clinicians are forced to treat these children less frequently and increasingly prescribe home-based interventions. Some literature on home exercise programs exists for children with developmental disabilities (DD) (Daichman, Johnston, Evans, & Tecklin, 2003; Harbourne, Willett, Kyvelidou, Deffeyes, & Stergiou, 2010; Katz-Leurer, Rotem, Keren, & Meyer, 2009; Lewis & Fragala-Pinkham, 2005; Novak, Cusick, & Lannin, 2009; Rickards, Walstab, Wright-Rossi, Simpson, & Reddihough, 2007), though most intervention research focuses on clinic based rehabilitation interventions. Clinicians need to provide documentation that the type of intervention utilized is not only appropriate, but makes a positive impact on the individual's function and quality of life.

The function and quality of life of an individual are influenced by many factors and for rehabilitation professionals are best described using the International Classification of Functioning (ICF), Disability, and Health model (World Health Organization, 2001). The ICF model recognizes that individual health status affects the person's activities, participation, environment, and other personal factors, as well as the body structures and functions. Use of the ICF model in rehabilitation directs the clinician and researcher to address activities, participation and environment in their plan of care, as well as limitations in body structure and function. A child and youth version of the ICF model (ICF-CY) was developed in 2007 to address the specific needs of children (World Health Organization, 2007). Use of the ICF model in rehabilitation has been widely supported by professional organizations, such as the American Physical Therapy Association (2009), American Occupational Therapy Association (2002), and American

Speech-Language Hearing Association (2007). Professionals can use the ICF model throughout the rehabilitation process: from examination and evaluation to designing a plan of care through discharge. While the ICF model is not a hierarchical model, one could argue that the most important component of the model is the child's activities and participation. A child's ability to participate in age-appropriate activities with his peers provides the child with socialization opportunities as well as movement opportunities. It has been well documented that children with DD who have greater physical abilities (fewer impairments) have higher intensities of participation (Maher, Olds, Williams, & Lane, 2008; Palisano et al., 2011; Van Naarden Braun, Yeargin-Allsopp, & Lollar, 2006). Giving children with DD an opportunity to improve their abilities may increase their intensity of participation.

Use of the ICF model for intervention planning and research guides both the clinician and researcher to address multiple components of the model to improve function and quality of life of children. Historically, pediatric intervention research focused on identifying improvements in body structures and functions for children with DD following interventions, and did not address changes in activities, participation, or quality of life. Recently, the ICF components of activities and participation have been addressed in intervention research. Valvano (2004) proposed an intervention model with two components of the ICF, activities and impairments (body structure and function), based on motor learning theory. She suggested that pediatric rehabilitation professionals integrate activities and impairments into interventions, and that these interventions be of interest to child and family. Using Valvano's model (2004) and ICF-CY (World Health Organization, 2007) pediatric rehabilitation professionals should design interventions that influence multiple facets of the child's health status, function, and quality of life.

Structuring these interventions into the everyday lives of children with cerebral palsy (CP) was the focus of an opinion article by Damiano (2009). She suggested that the future of intervention research should compare direct treatment by rehabilitation professionals to interventions structured within everyday life. While the suggestions proposed by Damiano (2009) are necessary, there is also a need to incorporate multiple components of the ICF model, especially activities and participation. A review of intervention studies established four general categories of research that addressed the ICF



components of body function impairments and limitations in activities for children with CP (Anttila, Suoranta, Malmivaara, Makela, & Autti-Ramo, 2008). The four categories were: 1) upper extremity intensive training on bimanual performance, 2) strength training, 3) hippotherapy and muscle symmetry and activities, and 4) balance training and reactive balance. Both articles (Anttila et al., 2008; Damiano, 2009) reinforce that all components of the ICF model be incorporated into intervention research, and though both articles focus on children with CP, the concepts can be applied to children with developmental disabilities (DD).

### **Balance Training Interventions**

Balance training is one of the categories identified by Anttila and colleagues (2008) that is evidence-based for clinical practice in children with CP. Balance training research has also included children who are typically developing (Sveistrup & Woollacott, 1997), children with hearing loss (Effgen, 1981; Rine et al., 2004) and children with lower limb amputations (Andrysek et al., 2012). Many intervention and exercise programs include balance components, but there are few research studies that focus solely on balance training for children with DD. Often balance is included not as an intervention, but as an outcome measure for children with DD (Harbourne et al., 2010; Katz-Leurer et al., 2009; Wang & Ju, 2002a; Wuang, Chiang, Su, & Wang, 2011). Balance training interventions for children with DD are important because balance is impaired when compared to typically developing peers (Chang, Wade, Stoffregen, Hsu, & Pan, 2010; Ferdjallah, Harris, Smith, & Wertsch, 2002; Galli et al., 2008), and may lead to decreased activity and participation.

Balance impairments are not independent of other impairments of body structures. Children with CP and Down syndrome (DS) have slower gait velocities (Hsue, Miller, & Su, 2009a; Kubo & Ulrich, 2006a; Liao, Jeng, Lai, Cheng, & Hu, 1997) and decreased lower extremity strength (Cioni et al., 1994; Lowes, Westcott, Palisano, Effgen, & Orlin, 2004; Mercer & Lewis, 2001). For children with CP a slower gait velocity may be a result of a decreased ability to weight-shift during gait (Wheelwright, Minns, Elton, & Law, 1993) and weak hip abductors (Metaxiotis, Accles, Siebel, & Doederlein, 2000). The slower gait velocity of children with DS has been attributed to increased kinematic movement of the pelvis in the medial-lateral direction during gait, muscle weakness, and

hypotonicity (Kubo & Ulrich, 2006a). Liao and colleagues (1997) suggest that one way to improve gait velocity in children with CP is to provide a balance training intervention focusing on rhythmic lateral weight shifting. Currently published literature on balance training for children with DD have used anterior-posterior (Shumway-Cook, Hutchinson, Kartin, Price, & Woollacott, 2003; Woollacott et al., 2005) or multi-directional intervention (Hartveld & Hegarty, 1996; Ledebt et al., 2005), but none focused solely on lateral weight shifting. A lateral only weight shifting intervention would assist children with CP or DS in controlling their motion in the medial lateral direction during gait (Hsue et al., 2009a; Hsue, Miller, & Su, 2009b; Kubo & Ulrich, 2006a), but may not translate to improved balance in other activities. Multi-directional balance training resembles movements utilized in activities of daily living and gait.

Balance training for children with CP has had two main training paradigms: perturbation-based (Shumway-Cook et al., 2003; Woollacott et al., 2005) and weight-shifting (Hartveld & Hegarty, 1996; Ledebt et al., 2005). Both paradigms primarily focused on body structures and function, and all but one did not use an activity based intervention model. Hartveld and Hegarty's (1996) study did utilize an activity based intervention model though it predates Valvano's model (2004), and included ICF model components of environment and personal factors. Their study was home-based using a custom-designed video game as motivation (Hartveld & Hegarty, 1996). The use of a video game is a novel activity that the participants enjoyed and wanted to continue, which may provide long-term reinforcement in the home environment of appropriate motor programs related to improved balance.

With the advent of video game technology that imitates virtual reality, balance training interventions are being researched in both healthy populations and individuals having many different diagnoses. The Nintendo Wii™ and WiiFit™ (Nintendo of America, Redmond, WA) has been utilized as a balance training intervention for healthy adults and was found to be more enjoyable than traditional balance training intervention (Brumels, Blasius, Cortright, Oumedian, & Solberg, 2008). Improvements in balance were found following training with the WiiFit in healthy adults (Brumels et al., 2008), children with CP (Deutsch, Borbely, Filler, Huhn, & Guarrera-Bowlby, 2008; Liu et al., 2009a), DS (Berg, Becker, Martian, Primrose, & Wingen, 2012; Wuang et al., 2011) and

individuals with lower limb amputations (Andrysek et al., 2012). The missing component of these studies, from the ICF model, is how the balance-training intervention affected the activities, participation and overall quality of life of the participants.

Only one study from the perturbation balance training literature partially addressed the activity limitations of children with CP. Shumway-Cook and colleagues (2003) included the Gross Motor Function Measure (Russell, Rosenbaum, Avery, & Lane, 2002) as a measure of activity limitations (Harvey, Robin, Morris, Graham, & Baker, 2008). The participants of the perturbation-based intervention demonstrated no change in gross motor function, likely due to a ceiling effect of the tool.

### **Research Design**

Using the ICF model, balance training intervention research needs to include multiple aspects, including body structure and function, activities, participation and the environment. New research should address balance from multiple perspectives, including clinical and laboratory measures. De Kegel and colleagues (2010) define clinical measures as the examination of the results of balance, while laboratory measures investigate the process of balance. While there can be overlap between clinical and laboratory measures, clinical measures must be cost effective and easy to administer. Clinical measures are also necessary so that practicing professionals can document changes in body structure and function necessary for reimbursement, while laboratory measures identify changes that occur in temporal and spatial domains. Clinical measures of balance include the timed up and go test (Williams, Carroll, Reddihough, Phillips, & Galea, 2005) and single leg stance time (Atwater, Crowe, Deitz, & Richardson, 1990; De Kegel et al., 2010). Other clinical measures appropriate to assess in a balance training intervention study would be gait velocity (Liao et al., 1997) and hip strength (Lowe et al., 2004). Balance abilities correlate to gait velocity (Liao et al., 1997), as well as hip strength (Lowe et al., 2004) in children with CP. In addition, Metaxiotis and colleagues (2000) postulated that decreased strength in the lower extremities contributes to slower gait velocities. All of these measures address only one aspect of the ICF, body structure and function, thus there is a clear need to address how a balance training intervention changes the activities and participation of a child with DD. Activities and participation

can be measured through survey tools, such as the Activities Scale for Kids (Young, Yoshida, Williams, Bombardier, & Wright, 1995).

While the measures of balance training intervention outcomes must address multiple components of the ICF, intervention design may be best addressed using both the ICF model (World Health Organization, 2007) and Valvano's activity based intervention model (2004). Her model stresses interventions through engaging activities that are of interest to the child and family. Therefore, a novel and motivating stimulus, such as the Nintendo Wii™ and WiiFit™ video game may provide a mechanism to improve participation in a balance training intervention. Video-game based balance training for children with CP began with Hartveld and Hegarty's (1996) study and transitioned to the Wii™ for children with DD (Andrysek et al., 2012; Berg et al., 2012; Deutsch et al., 2008; Liu et al., 2009a; Wuang et al., 2011). Video-game based balance interventions utilize Valvano's model of activity based intervention (2004) and allow for a postural control intervention that is not physically facilitated by the therapist. Dusing and Harbourne (2010) suggest that postural control interventions are more effective when children manipulate their own bodies through space, rather than being perturbed by therapists. It also incorporates lateral (Liao et al., 1997) and multi-directional weight-shifting (Hartveld & Hegarty, 1996; Ledebt et al., 2005). A video-game based balance training program is a novel way to improve the balance, gait, strength and activities for children with DD.

When investigating the effectiveness of novel intervention, single-subject design is an optimal format. Single subject design allows for intra-individual comparison with high experimental control and social validity. Replication across subjects, settings and variables increases the credibility and trustworthiness of results. While there are many types of single subject design, the multiple baseline design across participants and variables allows for comparison among subjects. The behaviors being studied do not have to be reversible, nor do they have to respond quickly, as in other single subject designs such as an alternating treatment design (Kazdin, 1982; Kennedy, 2005). Single subject design has been previously reported in balance training literature for children with DD and adults (Betker, Szturm, Moussavi, & Nett, 2006; Hartveld & Hegarty, 1996; Sackley & Baguley, 1993; Shumway-Cook et al., 2003; Woollacott et al., 2005).

This research sought to examine the effects of a video-game based multi-directional balance training intervention in two, single-subject design studies. The first study was a pilot study with children with CP, and the second study expanded to include children with multiple diagnoses.

### **Statement of the Problem**

There is minimal literature focused solely on balance training for children with DD, and of this literature the outcome measures have been primarily limited to body structures and function related to balance. Balance training intervention research needs to investigate how the intervention affects other body structures and functions that relate to balance abilities, as well as activities and participation.

### **Statement of Purpose**

The purpose of this single-subject design research was to determine the effect of a multi-directional video-game based balance-training intervention on the balance, gait velocity, strength and activities of children with disabilities between 5 and 10 years of age.

### **Aims**

The aims of this study were:

1. To evaluate the change in balance during and following a 6 week multi-directional, video game based balance-training intervention for children with disabilities between 5 and 10 years of age.
2. To assess the change in gait velocity during and following a 6 week multi-directional, video game based balance training intervention for children with disabilities between 5 and 10 years of age.
3. To investigate if there are changes in activities, as measured by the Activities Scale for Kids, following a 6 week multi-directional, video game based balance-training intervention for children with disabilities between 5 and 10 years of age.
4. To investigate how enjoyable and challenging a 6 week multi-directional, video game based balance-training intervention is for children with disabilities between 5 and 10 years of age.

## Hypotheses

### Pilot Study

#### **Balance.**

1. Weight bearing symmetry in static bilateral stance will improve (become more symmetrical) during and following a multi-directional, video game based balance-training intervention.
2. Center of pressure area and velocity will decrease during and following a multi-directional, video game based balance-training intervention.
3. Time to boundary will increase during and following a multi-directional, video game based balance-training intervention.
4. Time to complete the “Timed Up and Go” will decrease during and following a multi-directional, video game based balance-training intervention.

#### **Gait.**

1. Gait velocity will increase during and following a multi-directional, video game based balance-training intervention.

#### **Strength.**

1. Strength of the bilateral hip abductors will remain constant following a multi-directional, video game based balance-training intervention.

#### **Activities.**

1. Participation in activities, as measured by the Activities Scale for Kids, will remain constant during and following a multi-directional, video game based balance training intervention.

## Study Two

### **Measures of body structure and function.**

1. Weight bearing symmetry in static bilateral stance will fall between 48% and 52% during and following a multi-directional, video game based balance-training intervention.
2. Center of pressure area and velocity will decrease during and following a multi-directional, video game based balance-training intervention.
3. Time to boundary will increase during and following a multi-directional, video game based balance-training intervention.
4. Single leg stance time will increase during and following a multi-directional, video game based balance-training intervention.
5. Gait velocity will increase during and following a multi-directional, video game based balance-training intervention.
6. Strength of the bilateral hip abductors will increase during and following a multi-directional, video game based balance-training intervention.

### **Measures of activity limitations and participation restrictions.**

1. Participation in activities, as measured by the Activities Scale for Kids, will increase during and following a multi-directional, video game based balance training intervention.
2. Enjoyment of the multi-directional, video-game based balance training intervention will remain constant or increase as measured by the Enjoyment and Difficulty Questionnaire.
3. Perceived difficulty of the multi-directional video-game based balance training intervention will remain constant or decrease as measured by the Enjoyment and Difficulty Questionnaire.

## Operational Definitions

### General Terms

Balance: A generic term referring to the body's ability maintain a steady state.

Postural control: The act of maintaining or achieving or restoring posture to the desirable orientation.

### Diagnoses

Cerebral palsy: A non-progressive group of disorders that affect movement and posture that occurred from damage to the developing fetal or infant brain. There are often impairments in sensation, cognition, communication, perception, and behavior (Bax, Goldstein, Rosenbaum, Leviton, & Paneth, 2005).

Down syndrome (DS): A genetic disorder most frequently caused by an extra chromosome on chromosome pair 21, other variations of DS include translocation and mosaicism (Stoll, Alembik, Dott, & Roth, 1998).

Autism spectrum disorder (ASD): “the presence of markedly abnormal or impaired development in social interaction and communication and a markedly restricted repertoire of activity and interests” (American Psychiatric Association, 2000)

### Research Design

Single subject research design (SSRD): Single subject research design is a research design in which participants function as their own controls within a highly controlled experimental paradigm.

Multiple baseline design: A SSRD in which multiple participants, behaviors or settings are studied across time where an intervention is systematically applied.

### Outcome Measures

Activities Scale for Kids (ASK): A self-report 30 item questionnaire of activities that child has either performed or may be able to perform in the past week. Two versions exist: one is the performance, what the child has actually performed in the past week and the second is the capabilities, what the child is capable of doing in the past week (Young, Williams, Yoshida, Bumbardier, & Wright, 1996; Young et al., 1995).



Center of pressure (COP): A two dimensional measure of the three dimensional forces between the feet and a forceplate during stance.

Gait velocity (GV): The time it takes for a participant to ambulate 3 meters at their

standard pace. It was calculated as thus: 
$$GV = \frac{distance}{time}$$

Single limb stance time (SLST): The length of time a participant can maintain standing on one leg with hands on hips and knee flexed to 90°. The test is completed with the eyes open and the test is finished when the hands come off the hips, the flexed knee is no longer at 90° or 30 seconds is reached (Atwater et al., 1990).

Time to boundary (TTB): An analysis of the COP defined as the time it would take for the COP to reach the edge of the feet (boundary) if it continued on the same path without changing velocity or direction (van Emmerik & van Wegen, 2002).

## **Delimitations**

### **Participants**

1. Participants were limited to school age children between the ages of 5 and 10 years at the beginning of each study.
2. Participants were limited to school age children with a developmental disability.
3. Participants had to be able to complete a two-step direction.
4. Participants had to be able to ambulate.
5. Participants had to be able to stand without external support for 3 minutes.
6. Participants must have normal or corrected to normal vision.
7. Participants must not have a hearing impairment.

### **Environment**

1. All portions of the study were limited to the participant's home.
2. Participants must have access to a television.

### **Research Design**

1. Both studies are single-subject research design and limited by the aspects of this design.
2. The pilot study had a predetermined baseline length.
3. The second study had baseline lengths set between 5 and 10 sessions.

## **Chapter Two: Review of the Literature**

There is a large body of literature on postural control in healthy adults and children, and a growing body of literature on deficits in postural control in children with developmental disabilities (DD). To better understand how to address clinically the balance impairments of children with DD from an activity-based intervention model, the development of standing balance in typically developing (TD) children and children with DD must be understood. Balance assessment and intervention are part of clinical practice guidelines for children with spastic diplegia cerebral palsy (CP) and are recommended for children with other DD (O'Neil, Fragala-Pinkham, et al., 2006). The following chapter presents a review of literature divided into four sections: balance, including the sensory development of balance; children with DD; balance training; and technology and postural control.

### **Balance**

#### **Development of Balance**

Balance development has been studied in multiple positions, including sitting and stance. It is important to understand the development of postural control in stance, because children's balance abilities are correlated to their ability to perform activities of daily living (Engel-Yeger, Golz, & Parush, 2004) and may affect participation (Imms, Reilly, Carlin, & Dodd, 2008; Majnemer et al., 2008). Balance must be considered in multiple contexts: static and dynamic, and reactive and anticipatory. Static and dynamic balance refer to the relationship between movement of the center of mass (COM) and base of support (BOS), while reactive and anticipatory refer to the adjustments made to the COM and BOS. Static balance infers there is minimal movement between the COM and BOS, while during dynamic balance there is clear and purposeful movement between the COM and BOS. Reactive postural adjustments (RPA) are in response to some unexpected shift in the COM or BOS and, anticipatory postural adjustments (APA) are specific neuromusculoskeletal activation of the structures controlling the COM and/or BOS to accommodate an upcoming motion (Westcott & Burtner, 2004). Maintaining balance, regardless of context, requires use of the sensory and motor systems.

There are three primary sensory components utilized to maintain postural control: visual, somatosensory, and vestibular systems. Each component is unique in its contribution, but all three components are necessary for optimal postural control. The visual, somatosensory and vestibular systems process different information about the body and environment with respect to gravity and motion. They are designed to be redundant, allowing the body to sort the information to make the necessary adjustments, or function with an impaired system, such as in an individual who is blind.

In adults the sensory systems integrate visual, vestibular and somatosensory information to assist in the maintenance of balance. Children use the three systems differently when maintaining their balance compared to adults. As children develop both physically and motorically each of these systems matures at an individual rate, until eventually reaching an adult-like state. Even when all three sensory systems are in adult-like states an adolescent may still not have the sensory responses and organization similar to an adult (Nolan, Grigorenko, & Thorstensson, 2005). Adult-like responses to postural control perturbations are hypothesized to use a “closed-loop” system, based on the integration of information from the visual, vestibular and somatosensory systems, whereas children under 8 years are thought to use an “open-loop” system relying on ballistic corrections to their COP to maintain the COM within the BOS (Kirshenbaum, Riach, & Starkes, 2001; Riach & Starkes, 1994). The following is a discussion of the development of standing balance from the perspective of the three sensory systems in TD children.

### **Vision.**

The visual system is the dominant system for balance in early walkers in combination with the somatosensory system (Sundermier & Woollacott, 1998). After learning to walk, and for children under 3 years, vision continues to dominate, with some reliance on the vestibular system (Foudriat, Di Fabio, & Anderson, 1993; Shumway-Cook & Woollacott, 1985b). While TD children may be dependent on visual information to maintain balance, the visual system is not yet mature. Step-like improvements of the visual system occur at 5 through 6 years and 11 through 13 years (Hirabayashi & Iwasaki, 1995). The improvements between these two ages have created two theories for the maturation of the visual system, assuming that it continues to develop beyond age 10

years. One theory is that the visual system is adult like between 11 (Peterson, Christou, & Rosengren, 2006) and 14 years (Ferber-Viart, Ionescu, Morlet, Froehlich, & Dubreuil, 2007). The second theory is that it is thought to mature between 14 (Hirabayashi & Iwasaki, 1995) and 16 years (Cumberworth, Patel, Rogers, & Kenyon, 2007; Steindl, Kunz, Schrott-Fischer, & Scholtz, 2006). One of the markers used to determine maturation is postural sway, and many assessments focus primarily on anterior-posterior (AP) postural sway.

Females develop AP control that is adult-like with vision by 12 to 13 years, while males develop AP control over two time periods: 9 through 10 years and 15 through 16 years. At 9 through 10 years and 16 through 16 years males exhibit a visual control strategy that is adult-like (Nolan et al., 2005), indicating that the changes in center of pressure (COP) data reflect the use of a closed loop strategy (sensory) to maintain balance (Riach & Starkes, 1994). At 12 and 13 years males are not demonstrating the adult-like strategy in the AP direction and have a decreased AP sway velocity and total path length (Nolan et al., 2005). This U shaped pattern is reflective of the motor learning paradigm, where a behavior increases its variability and may worsen before refining and returning to original levels (Adolph, Berger, & Leo, 2011; Thelen, Corbetta, & Spencer, 1996). When using measures that account for medial-lateral (ML) control of postural sway, the visual system is still developing at 15 through 16 years (Nolan et al., 2005). It is likely that the visual system matures between 14 and 16 years (blue arrow, Figure 2.1) when including both sexes, and AP and ML postural sway. The maturation of the visual system is important to postural control, because in the absence of visual strategies to help maintain balance, TD children switch to predominantly hip and ankle strategies, rather than ankle alone (Ferdjallah et al., 2002), which is considered a mature response. An ankle strategy is when the primary response to maintain upright stance occurs at the ankle joint with activation of the gastrocnemius and tibialis anterior muscles (Woollacott & Sveistrup, 1992).

### **Somatosensory system.**

The somatosensory system becomes a primary system of balance with assistance from the vestibular system around 3 years of age (purple arrow, Figure 2.1), (Foudriat et al., 1993). During the first three years of life the somatosensory systems appears to be

undergoing rapid changes and maturation, and by 3 to 4 years this system is the most mature and adult-like (blue arrow, Figure 2.1), (Cumberworth et al., 2007; Hirabayashi & Iwasaki, 1995; Steindl et al., 2006; Woollacott, Debu, & Mowatt, 1987). For TD children 6 years and older the somatosensory system is used primarily in the maintenance of balance (Rine, Rubish, & Feeney, 1998). Research has not revealed any further changes in the maturation of the somatosensory system or any gender differences.

### **Vestibular system.**

The vestibular system is used in conjunction with both the visual and somatosensory systems, and is never considered the primary system to maintain balance in TD children (purple arrows, Figure 2.1). In those under 3 years of age it is used in combination with the visual system, (Foudriat et al., 1993; Shumway-Cook & Woollacott, 1985b) and over 3 years in conjunction with the somatosensory system (Foudriat et al., 1993). The vestibular system is the slowest developing system, and the most at risk for permanent damage due to repeated episodes of middle ear effusion, a common childhood illness (Casselbrant et al., 2000).

In contrast to Shumway-Cook and Woollacott's (1985b) early work, current research has demonstrated that the vestibular system is still developing between 7 and 10 years (Cherng, Chen, & Su, 2001; Nolan et al., 2005; Rine et al., 1998; Steindl et al., 2006) and even between 12 and 14 years (Ferber-Viart et al., 2007; Shimizu, Asai, Takata, & Watanabe, 1994; Steindl et al., 2006). Between 7 and 10 years the vestibular system is not as efficient as in an adult (Cherng et al., 2001) and children are unable to balance effectively with only vestibular input (Woollacott & Shumway-Cook, 1990). Though the vestibular system may not be as efficient, children between the ages of 5 and 7.5 years are able to use vestibular input (Cherng et al., 2001; Forssberg & Nashner, 1982; Steindl et al., 2006). Step-like improvements in the development of the vestibular system have been observed between 7 and 8 years and 14 and 15 years (Hirabayashi & Iwasaki, 1995). One study found the vestibular system to be adult like (postural sway area) in stance at 12 years, (Peterson et al., 2006) though other research considers the vestibular system to be developing until 14 to 16 years (blue arrow, Figure 2.1, (Cherng et al., 2001; Cumberworth et al., 2007; Hirabayashi & Iwasaki, 1995; Steindl et al., 2006) comparable to the visual system.

There appears to be differences between the genders during development in the vestibular system, similar to the visual system. Multiple studies have noted that vestibular system performance is better in females than males, specifically around the ages of 7 to 8 years (Hirabayashi & Iwasaki, 1995; Peterson et al., 2006; Shimizu et al., 1994). Peterson and colleagues (2006) speculate that it may be due to leisure activities and exposure, more than true developmental changes, as females under age 10 years are often engaged in balance challenging activities, thus the vestibular system is being tested more frequently. Males under 10 years are more often engaged in physical activities, such as running or soccer, or sedentary activities, such as video games, where the vestibular system is not as frequently challenged, which may result in a difference during testing (Peterson et al., 2006).

#### **Use of conflicting sensory information.**

The ability to use and re-weight sensory information during balance activities improves with age in TD children (Bair, Kiemel, Jeka, & Clark, 2007; Peterson et al., 2006). Children as young as 3 to 6 years old have demonstrated the ability to manage conflicting sensory information during balance testing (Foudriat et al., 1993; Steindl et al., 2006), which contrasts with early work (Forssberg & Nashner, 1982; Shumway-Cook & Woollacott, 1985b). Early research reported there was little coordination between the sensory systems, with random weighting of information under 7 years of age (Forssberg & Nashner, 1982). More current research supports that even though the vision, vestibular and somatosensory systems are still maturing children are able to complete balance testing that threaten the individual systems (Hirabayashi & Iwasaki, 1995; Peterson et al., 2006; Rine et al., 1998; Steindl et al., 2006). As children mature they are better able to manage the information derived from the sensory systems, and sensory organization is considered mature and integrated in adolescence around 15 years of age (Steindl et al., 2006).

#### **Postural sway.**

Postural sway is one form of assessing postural control. Children have an increased and more variable postural sway compared to healthy adults (Forssberg & Nashner, 1982). Not only is sway greater, but children sway at a higher velocity than

adults (Forssberg & Nashner, 1982). Thus children need faster muscular responses to threats to their balance, which is managed by the somatosensory system (Roncesvalles, Woollacott, & Burtner, 2002). Postural stability increases with age, with decreases in variance, velocity and frequency of sway during stance with both eyes open (EO) and closed (EC), (Cumberworth et al., 2007; Foudriat et al., 1993; Riach & Hayes, 1987; Rine et al., 1998; Wolff et al., 1998).

Control over the AP axis develops faster than ML (Hong, James, & Newell, 2008). It has been demonstrated that AP postural sway decreases by 5% between the ages of 5 through 18 years, while ML sway decreases by 25% over the same age range (Wolff et al., 1998). There is also some evidence to support gender differences in the maturation of postural sway. Females tend to have more ML instability than males at 9 through 10 years of age, though this resolves between 12 and 13 years (Nolan et al., 2005).

#### **Anticipatory and reactive balance.**

TD children maintain their standing balance through a series of strategies utilizing APAs and RPAs. APAs are the internal adjustments made prior to a voluntary movement, while RPAs are the adjustments made following an unexpected perturbation (Westcott & Burtner, 2004). In stance, as early as 10 months TD children begin to exhibit APA, and it becomes more consistent and temporally appropriate as the experience of walking increases (Assaiante, Mallau, Viel, Jover, & Schmitz, 2005). When children begin to master independent walking they transition from RPA to APA in stance around 13.5 months (Barela, Jeka, & Clark, 1999). A true APA begins around 13-14 months, is well developed by 16-17 months, and after 15 months of age an APA can be scaled in magnitude to the task (Witherington et al., 2002). APA's can be observed in a child's center of pressure (COP) tracings by as early as 4 years of age in both the AP and ML directions (Riach & Hayes, 1990). By 7 years of age children are able to generate adult like APAs (Girolami, Shiratori, & Aruin, 2010). APAs are clearly task specific, and follow a general pattern of muscle co-contraction when presented with a new movement pattern, but become more variable and less dependent on co-contraction as experience with the task occurs (Vereijken, van Emmerik, Whiting, & Newell, 1992).

RPAs in stance begin as early as 7 to 8 months in infants who begin to demonstrate ankle strategies (Sveistrup & Woollacott, 1996; Woollacott & Sveistrup,



1992), and continue to follow an adult-like pattern of muscle coordination distally to proximally until 4 to 6 years of age (Forssberg & Nashner, 1982). At 4 to 6 years of age variability increases in RPAs, specifically in muscle coordination, but returns to adult-like patterns by 7 to 10 years of age (Forssberg & Nashner, 1982).

### **Critical period.**

There are transitional periods of postural control at 3, 6, 9 to 10, 13 to 14 months (Hadders-Algra, 2005), 4 to 5 years (Foudriat et al., 1993), 6 to 7 years (Baumberger, Isableu, & Fluckiger, 2004), and 8 to 10 years (Figura, Cama, Capranica, Guidetti, & Pulejo, 1991). These transitional periods of postural control represent changes early in life of dominance shifts and maturation of the systems (red stars, Figure 2.1). Separate from the transitional periods, is a theoretical critical period of balance development between 3 and 7.5 years (Forssberg & Nashner, 1982; Rine et al., 1998; Woollacott et al., 1987). During static stance with non-conflicting sensory input there are significant changes in postural sway between 4 and 5 years of age (Foudriat et al., 1993), between 6 and 8 years, and 8 through 10 years (Figura et al., 1991). The 4 to 6 years age period is also when the RPAs demonstrate increased variability away from adult-like patterns (Forssberg & Nashner, 1982). These significant changes further support the idea of a critical period of balance development. Based on the changes in postural sway (Figura et al., 1991; Foudriat et al., 1993) and RPAs (Forssberg & Nashner, 1982) between 4 and 8 years of age, and stance becoming adult-like at 7 to 8 years (Steindl et al., 2006), it appears that between 3 and 8 years of age is a critical time to address balance impairments.

### **Summary.**

TD children are dependent on the input from visual, somatosensory and vestibular systems to maintain their balance. Each sensory system has its own maturation timeline (Figure 2.1). A clear pattern exists as the infant progresses from somatosensory dominance in the first year of life to the utilization of the visual system. It is only shortly after the dominance of the visual system that the vestibular system is utilized. This stair-step like effect demonstrates the rapid neurological adaptations that young children are undergoing. These adaptations are most evident around 3 years of age when shifts from

visual and vestibular dominance to somatosensory and vestibular dominance occur. During this shift the somatosensory system appears to be undergoing rapid maturation, while the visual and vestibular systems take longer to mature. The vestibular system may have a longer maturation period because it has been used in conjunction with the primary systems since 1.5 years of age.

The critical period of development for postural control in TD children begins with the dominance shift and maturation of the somatosensory system (red arrow, Figure 2.1). These two key elements may be part of the reason that 3 through 7.5 years is a critical age for balance development in TD children, as well as the changes in RPAs. This critical period may be one of the best times to address balance impairments in children with DD.

### **Children with Developmental Disabilities**

This section discusses three common diagnoses of children with DD and their impairments of body structures and function, as well as their limitations in activities and participation. A focus of how these impairments impact postural control is presented.

#### **Cerebral Palsy**

CP is a non-progressive group of disorders that affect movement and posture that occurred from damage to the developing fetal or infant brain. There are often impairments in sensation, cognition, communication, perception, and behavior (Bax et al., 2005). In the United States the prevalence of CP is 3.6 per 1,000 live births (Yeargin-Allsopp et al., 2008), making it one of the most common developmental disorders.

Children with CP are now often classified using functional classifications, the Gross Motor Function Classification System (GMFCS), (Palisano et al., 1997; Palisano, Rosenbaum, Bartlett, & Livingston, 2008) and the Manual Ability Classification System (MACS), (Eliasson et al., 2006). Both classification systems are five level systems (I-V) with level one being least involved and five most involved. The GMFCS and MACS are highly correlated (Eliasson et al., 2006), though measure different constructs of function. The GMFCS measures mobility, while the MACS measures upper extremity use. Children with CP at levels I or II on the GMFCS are able to ambulate without an assistive device, while level III marks the transition to ambulating with an assistive device. On both the GMFCS and MACS level III is a transitional level and typically when grouping

the levels, level III aligns closely with IV and V (Palisano et al., 1997). The type and severity of CP can predict balance abilities (Nashner, Shumway-Cook, & Marin, 1983; Rose et al., 2002).

### **Down Syndrome**

Down syndrome (DS) is a genetic disorder most frequently caused by an extra chromosome on chromosome pair 21. Other variations of DS include translocation and mosaicism (Stoll et al., 1998). The prevalence rate of children with DS in the United States ranges from 13.08 to 13.48 per 10,000 live births (Parker et al., 2010). Children with DS have impairments in muscle tone and strength (Cioni et al., 1994), the cardiopulmonary (Freeman et al., 1998), visual (Merrick & Koslowe, 2001; Tsiaras, Pueschel, Keller, Curran, & Giesswein, 1999) and vestibular systems (Igarashi, Takahashi, Alford, & Johnson, 1977). There is global delay in gross and fine motor skills, bimanual coordination, and static and dynamic balance (Connolly & Michael, 1986; Spano et al., 1999; Wang & Ju, 2002b).

### **Autism Spectrum Disorder**

Children with autism spectrum disorder (ASD) primarily have impairments in communication and social interaction, though recent literature supports the prevalence of motor impairments (Fournier, Hass, Naik, Lodha, & Cauraugh, 2010). While there is a wide range of abilities in a child with ASD, the diagnosis is defined as “the presence of markedly abnormal or impaired development in social interaction and communication and a markedly restricted repertoire of activity and interests” (American Psychiatric Association, 2000). Though the official diagnosis focuses on the communicative and social aspects of ASD, there are impairments in motor control and coordination (Bhat, Landa, & Galloway, 2011; Fournier, Hass, et al., 2010), visual perception (Kaiser & Shiffrar, 2009), sensory systems (Klintwall et al., 2011), and muscle tone (De Jong, Punt, De Groot, Minderaa, & Hadders-Algra, 2011). The prevalence rate of ASD continues to increase with 1 child in 88 having ASD, with males being 5 times more likely to be diagnosed than females (Centers for Disease Control and Prevention, 2012). With the growing number of children being diagnosed with ASD there is a significant need for clinicians to also address impairments other than communication of children with ASD.

## **Impairments of Body Structure and Function**

CP, DS, and ASD are diagnoses that have a wide range of impairments of body structures and functions, many of which impact postural control. Sensory impairments are common in children with DD (Gal, Dyck, & Passmore, 2010; Leekam, Nieto, Libby, Wing, & Gould, 2007; Nashner, 1985), and they are at an increased risk for visual impairments (Creavin & Brown, 2009; Kaiser & Shiffrar, 2009; Kozeis et al., 2007; Merrick & Koslowe, 2001; Simmons et al., 2009; Tsiaras et al., 1999). Visual deficits are most common in children with CP (Kozeis et al., 2007), especially as the severity of CP increases (Ghasia, Brunstrom, Gordon, & Tychsen, 2008). Vestibular impairments are also common in children with CP (Nashner, 1985; Takiguchi et al., 1991), those with ASD (Maurer & Damasio, 1979) and children with DS (Igarashi et al., 1977). These impairments of the visual, vestibular and somatosensory systems are only one component of the impaired balance abilities of children with DD. Another important component is their timeline of balance development. Because most children with DD have delayed motor milestones compared to TD children (Hanna et al., 2009; Palisano et al., 2001), it can be inferred that postural control development is also delayed.

### **Balance.**

#### *Visual system.*

Research has not focused on the developmental timeline of balance for many pediatric diagnoses; the majority of research on standing balance development has been performed on children with CP and to a lesser extent on children with DS. Infants with DS are more susceptible to visual perturbations than TD infants and exhibit an increase in sway and the number of falls (Butterworth & Cicchetti, 1978). Shumway-Cook and Woollacott (1985a) reported that young children with DS appear more reliant on their visual system than TD children. Children with CP are highly dependent on visual input for balance at age 3 years in stance, similar to TD children, though visual information is not processed the same manner as TD children (Woollacott & Burtner, 1992). Between 7 and 9 years the dependence on vision decreases for children with CP (Woollacott & Burtner, 1992). There is no difference in the use of vision for postural control in children with CP and those TD between 5 and 18 years of age (Rose et al., 2002). Similar results

are found in TD teenagers and teenagers with DS, though balance abilities differ (Vuillerme, Vuillerme, Marin, & Debu, 2001). Children with CP and those with DS appear to follow a similar timeline in the use of visual information to maintain balance.

In contrast to children with CP and with DS, children with ASD do not utilize visual information in the same way, and there is no literature discussing their development of the visual system in relation to postural control development. Children with ASD have been reported to have a hyporeactive response to visual motion stimulus during balance tasks, specifically displaying minimal shifts in COP data (Gepner, Mestre, Masson, & de Schonen, 1995; Gepner & Mestre, 2002). The only similarity between children with ASD, CP or DS to TD children is an increase in COP area with EC, though the area is greater for children with ASD than TD children (Molloy, Dietrich, & Bhattacharya, 2003). The use of the visual system in the maintenance and development of postural control has yet to be clearly defined for children with ASD. Some authors (Gepner et al., 1995; Gepner & Mestre, 2002) speculate that visual information is disregarded in children with ASD during balance tasks due to underlying sensory impairments, though further investigation is necessary.

### ***Somatosensory system.***

Research suggests that the use of the somatosensory system is poor in children with CP and with DS during balance tasks (Nashner et al., 1983; Shumway-Cook & Woollacott, 1985a). When sensory information is unreliable, such as standing on an unstable surface, the use of the somatosensory system is poor in children with CP (Liao et al., 1997). Between 4 and 6 years of age children with DS have difficulty completing postural control tasks that challenge the somatosensory system (Shumway-Cook & Woollacott, 1985a). At age 6 and 7 years children with CP perform the same balance task comparable to same age TD children when somatosensory input is reliable (stable surface) (Cherng, Su, Chen, & Kuan, 1999). What is different about the somatosensory system in children with CP is that they rely more heavily on the somatosensory system and thus demonstrate a greater difficulty switching between systems (Cherng et al., 1999).

Adolescents with DS utilize somatosensory input, though their balance differs from TD adolescents (Vuillerme et al., 2001). The literature on adults with DS supports an impairment in the somatosensory system (Cabeza-Ruiz et al., 2011; Carvalho &

Almeida, 2011; Gomes & Barela, 2007), though they are able to utilize light touch to decrease postural sway and sway velocity (Gomes & Barela, 2007). There is a clear need to identify when and how the somatosensory system is utilized to maintain stance in children with DS.

There is a paucity of research on the use of the somatosensory and postural control for children with ASD. Kohen-Raz and colleagues (1992) were the only ones to suggest that children with ASD may prefer using the somatosensory system to maintain balance. The majority of research on postural control and children with ASD has focused on either visual input or static stance with eyes open or closed, with no manipulation of the somatosensory system. More research is needed to support or refute Kohen-Raz and colleagues' (1992) theory that these children may have a preference to use the somatosensory system during balance tasks.

#### ***Vestibular system.***

Similar to the visual and somatosensory systems, there is minimal research on the development of the vestibular system for children with CP, DS or ASD. Research does demonstrate that children with CP tend to have no or minimal responses to vestibular stimulation (Takiguchi et al., 1991), suggesting a very poorly functioning vestibular system. The vestibular system of children with CP may be developing slower than TD children because of a lack of experience with vestibular challenges. When the vestibular system is forced to become the primary mechanism for postural control, children with CP have a difficult time interpreting vestibular information (Cherng et al., 1999). In children with CP it appears that the vestibular system does not function as a reference system as in TD children. No research data has been identified that addressed the timeline of vestibular maturation for children with CP or with DS. Research does suggest that adults with DS rely heavily on their vestibular system due to a deficit in their somatosensory system (Cabeza-Ruiz et al., 2011; Carvalho & Almeida, 2011). The literature does not address the vestibular system for children with ASD. The vestibular system is the least addressed system of those responsible for the maintenance of balance, possibly because it is primarily used in conjunction with other systems. With the high incidence of hearing impairments and possible vestibular impairments in children with DD investigating the use of the vestibular system during stance is clearly needed.

### ***Use of conflicting sensory information.***

Children with DD struggle with postural control when the sensory information is in conflict. During conflicting sensory information balance challenges older children with CP resembled TD children under 7 years of age (Nashner et al., 1983). Children with spastic hemiplegia CP had difficulty with coordination of muscle activation, while children with ataxic CP had difficulty with organizing sensory information. Children with diplegia CP had difficulty with both muscle activation and sensory organization (Nashner, 1985). Adapting and integrating sensory information is also difficult for children with DS between 4 and 6 years of age (Shumway-Cook & Woollacott, 1985a). There is no literature reporting how children with ASD manage conflicting sensory information during stance.

### ***Postural sway.***

Children with DD are known to have different postural sway area and velocity of sway, than TD children. Children with CP have greater postural sway, and sway more often than TD children (Donker, Ledebt, Roerdink, Savelsbergh, & Beek, 2008). Children and young adults with DS also sway over a greater area than their TD peers in dual limb and single limb stance (SLS), (Cabeza-Ruiz et al., 2011; Galli et al., 2008; Kokubun et al., 1997; Vuillerme et al., 2001).

In contrast to children with CP and with DS, children with ASD first appear more stable than TD children. Repeated studies indicate that children with ASD have smaller COP shifts during stance and decreased variability (Fournier, 2008; Gepner et al., 1995; Gepner & Mestre, 2002; Kohen-Raz et al., 1992). Smaller shifts in COP during static stance and decreased variability suggest that children with ASD have less available options when balance is threatened. The smaller shifts in COP may be due the larger COP area that children with ASD exhibit (Fournier, 2008; Molloy et al., 2003), which is indicative of a decrease in postural stability. Children with ASD have increased sway in the ML direction, in contrast to TD children and adults (Fournier, 2008). There are clear differences in the postural sway of children with DD compared to TD, and for children with ASD it may be attributed to non-typical sensory processing (Gal et al., 2010). If children with ASD do not process sensory information similar to TD children there will



be impairments in balance, motor control, and coordination, which is often demonstrated in increased clumsiness (Fournier, Hass, et al., 2010; Ghaziuddin & Butler, 1998).

### ***Reactive postural adjustments.***

Children with DD have a more difficult time maintaining their balance than TD children during balance threats. When undergoing perturbation testing children with CP tolerate fewer perturbations than age-matched peers and fewer than younger TD children (Chen & Woollacott, 2007), and there is an increased COP path length, directional changes and time to stabilization (Burtner, Woollacott, Craft, & Roncesvalles, 2007). Children with CP activate the hip, knee and ankle simultaneously during perturbation challenges, rather than sequentially (Chen & Woollacott, 2007). When the muscular responses are sequential, they are in the reverse order (proximal to distal) as compared to TD children (Woollacott & Burtner, 1996). Children with CP exhibit longer onset latency for muscle activation as compared to age-matched peers and younger TD children (Burtner, Qualls, & Woollacott, 1998; Chen & Woollacott, 2007). Specifically, the gastrocnemius did not change muscle activity in response to increasing perturbation magnitudes (Roncesvalles et al., 2002). To describe how poorly children with CP respond to perturbation, children with CP between the ages of 8 to 13 years correspond to TD children between the ages of 4 to 8 years (Chen & Woollacott, 2007). The RPAs of children with CP are clearly more delayed and impaired than TD children.

The RPA of children with DS demonstrate slower onset latencies in response to a perturbation and during sway they sway closer to their stability limits than TD children (Shumway-Cook & Woollacott, 1985a). In contrast to children with CP, children with DS have sequentially appropriate (distal to proximal) muscular responses in response to a perturbation (Shumway-Cook & Woollacott, 1985a). Adults with DS will also use a pattern of co-contraction to maintain their balance during threats (Carvalho & Almeida, 2011). No clear conclusions can be stated about the RPAs of children or adults with DS.

None of the balance literature for children with ASD has addressed response to perturbations or reactions to any balance threats. There is a clear need to determine the RPAs of children with ASD.



### *Anticipatory postural adjustments.*

The APAs of children with DD are also impaired. Children with CP exhibit APAs during forward reach tasks, but in comparison to age-matched TD peers the APA has a later onset time and increased variability (Westcott, Zaino, Unanue, Thorpe, & Miller, 1998). The COP of children with CP during reach tasks tends to exhibit one of two patterns of APA, a stiff resting pattern or a pattern of increased variability of COP (Liu, Zaino, & McCoy, 2007). These two patterns demonstrate that children with CP have less flexibility in their movement patterns when performing common tasks. Liu and colleagues (2007) suggest that intervention programs should include tasks that use APAs, so that children with CP can have access to more motor patterns in their daily life.

There is extremely limited research on the APAs of children with DS. There is one study that reported decreased anticipatory abilities of children with DS during the task of stepping over obstacles while ambulating (Virji-Babul & Brown, 2004). Children with DS demonstrated an increased variability in step length and lower toe clearance in comparison to TD children. Children with DS also frequently stopped in front of the obstacles before clearing them, reflecting a need for increased time to interpret the information about the obstacle and decreased APAs. Based on the results from Virji-Babul and Brown's (2004) study children with DS could benefit from intervention focused on APAs, especially during gait.

Similar to the lack of literature on RPAs in children with ASD there is no specific literature on APAs. The closest literature would be Founier's (2008) dissertation that investigated gait initiation. She found that during gait initiation children with ASD had decreased COP movement in the ML direction and increased variability in the AP direction as compared to TD children. These deviations suggest that children with ASD may be impaired in their APAs, though further research is necessary.

In summary there are significant differences between children with a DD and TD children in development of postural control in stance and characteristics of balance abilities. Children with CP have a greater postural sway at a faster velocity and over a larger area with decreased variability, while children with DS sway over a larger area. Children with ASD sway over a larger area with fewer movements within the area and

are less reactive to visual stimuli. Children with these diagnoses have difficulties processing sensory information during stance, albeit in different degrees.

### **Range of motion, strength and sensation.**

Impairments in range of motion (ROM), strength and sensation can impact the postural control abilities of children with DD. Decreases in ROM of hip extension and external rotation; ankle dorsiflexion and eversion are related ( $r^2= 0.54$  for ROM and strength) to how well children with CP can balance (Lowes et al., 2004). The limited lower extremity ROM of children with CP changes biomechanical alignment, which will influence postural control abilities (Woollacott & Burtner, 1996). With decreased available ROM, children with CP have less biomechanical range to allow for corrections to challenges to their balance and less range to prepare themselves for movements. This reduction in available range puts children with CP at a distinct disadvantage as compared to their TD peers. When TD children are asked to assume the crouch posture that children with spastic diplegia assume; TD children demonstrate muscular responses similar to children with spastic diplegia CP (Burtner et al., 1998).

The poor biomechanical alignment exhibited by children with CP will affect the ability to generate effective muscular contractions. Children with CP have impaired force production, which may severely limit standing balance (Lowes et al., 2004). Roncesvalles and colleagues (2002) suggest that insufficient postural muscle activity may be the primary cause of poor balance in children with CP. The impaired force production and insufficient activation exhibited by children with CP will contribute to postural control abilities. Prediction of these abilities was found by examining the strength of the ankle dorsiflexors, plantarflexors, quadriceps, hamstrings and hip abductors ( $r^2= 0.41$ ) (Lowes et al., 2004). The decreased strength exhibited by children with CP also correlates to functional ability, measured by the Gross Motor Function Measure (GMFM), (Russell et al., 2002). The overall GMFM-66 score was predicted by aggregate strength of the hip abductors and adductors, knee flexors and extensors, and ankle plantarflexors and dorsiflexors ( $r^2= 0.83$ ) (Ross & Engsborg, 2007); the ankle plantarflexors and hip flexors ( $r^2= 0.73$ ) (Eek & Beckung, 2008); and the knee extensors ( $r^2= 0.57$ ) (Damiano, Martellotta, Sullivan, Granata, & Abel, 2000). Hip abductors and ankle plantarflexors

predicted dimension D of the GMFM ( $r^2= 0.64$ ), while dimension E was predicted by the hip abductors and hamstrings ( $r^2= 0.63$ ) (Eek & Beckung, 2008).

Comparing the strength and ROM literature as it relates to balance and function in children with CP, there are many similarities in the joints and muscles identified. The hip and the ankle joints and musculature appear the most often in the literature relating to balance and function. At the ankle the primary motion is dorsiflexion with the dorsiflexors reported frequently for strength relationships with balance and the GMFM (Eek & Beckung, 2008; Lowes et al., 2004; Ross & Engsborg, 2007). The hip abductors appear most often in the strength and ROM literature as it relates to balance and function for children with CP. In studies where hip abduction was measured either through ROM or strength in relation to balance or function it was always identified as a statistically important variable.

The sensory impairments of children with CP are highly variable and different from those of TD children (Kenney, 1963). Research indicates that children with CP have deficits in both tactile sensation (McLaughlin et al., 2005; Wingert, Burton, Sinclair, Brunstrom, & Damiano, 2008) and proprioception for the upper and lower extremities (Wingert, Burton, Sinclair, Brunstrom, & Damiano, 2009). Tactile impairments were demonstrated in the bilateral upper extremities for children with diplegia and hemiplegia CP (Wingert et al., 2008). The proprioceptive impairments for children with diplegia and hemiplegia CP were decreased kinesthesia and joint position sense independent of motor ability for the upper and lower extremities (Wingert et al., 2009). These children had limitations in their ability to reproduce movements regardless of their motor abilities. Research suggests that children with CP have global deficits in their sensory abilities, which contribute to balance impairments. The deficits in tactile, kinesthesia and joint position sense present an interesting puzzle as it is thought that during balance activities children with CP rely most heavily upon their somatosensory system (Cherng et al., 1999).

There is significantly less literature available on the strength, ROM and sensation for children with DS and those with ASD, especially in regards to how it relates to balance and function. The hip abductors of children with DS have been reported to be weak (Mercer & Lewis, 2001). Minimal literature exists correlating the strength and

function of children with DS. A mild correlation has been reported between lower extremity strength, ROM, and motor abilities ( $r^2= 0.38$  strength, 0.46 ROM) of children with DS (Dichter, 1994). There is little in the literature describing correlations between gait, function and hip strength for children with DS, as there is for children with CP, though one can hypothesize that weakness in the hip abductors of the child with DS may present similar impairments in weight shifting, gait and balance. Another impairment for children with DS that is similar to those with CP is poor biomechanical alignment at the feet (Genaze, 2000). Children with DS are known to over-pronate and can improve their balance abilities following the application of a flexible supramalleolar orthosis (Martin, 2004). There is a significant lack of research on the strength and ROM on children with ASD.

### **Gait.**

The gait of children with DD is significantly different from TD children. One of the primary differences for ambulating children with CP is a slower gait velocity (GV) than TD children, for both self-selected GV and fast-walking pace (Wheelwright, Minns, Elton, et al., 1993; Wheelwright, Minns, Law, & Elton, 1993; White, Agouris, Selbie, & Kirkpatrick, 1999). The normalized GV of children with DS was not different than TD children, but the non-normalized GV was slower (Kubo & Ulrich, 2006a). The GV of children with ASD has not been found to be significantly different from TD children (Vernazza-Martin et al., 2005). For children with CP, GV was correlated to their functional ability, as measured by the GMFM (Russell et al., 2002) total score and dimensions D and E (Drouin, Malouin, Richards, & Marcoux, 1996). Although for children with CP who have velocities larger than 45 cm/s dimension E is not discriminative (Drouin et al., 1996). Slower GV may be caused by a decreased ability to rhythmically weight shift in children with CP (Liao et al., 1997). Weight shifting has not been investigated in children with DS or those with ASD, though it can be hypothesized that this impairment may exist based on their balance and gait characteristics.

Children with hemiplegic CP are less able to weight shift onto their paretic side during ambulation (Wheelwright, Minns, Elton, et al., 1993). Weight shifting is a critical ability to facilitate smooth and efficient gait. The gait of children with CP often present with increased spinal and pelvic motion (Romkes et al., 2007), which may be a result of

weak hip abductors (Metaxiotis et al., 2000) and hyperactive trunk musculature (Prosser, Lee, VanSant, Barbe, & Lauer, 2010). Those children with spastic diplegia and hemiplegia CP have impaired abilities to move their COM and COP medially and laterally during gait (Hsue et al., 2009a, 2009b). They also have an increased ML displacement of their COP and COM, as well as an increased ratio of COM to COP. The increased ML movement of COM and COP during gait leads to gait deviations of increased step width (Hsue et al., 2009a, 2009b) and decreased step length (Wheelwright, Minns, Elton, et al., 1993). There is also less movement of the COM and COP in the AP direction for children with CP, as compared to TD peers (Hsue et al., 2009a, 2009b).

The limited motions of COM and COP for children with CP are reflected in the gait cycle during time spent in stance and swing phases. For stance phase, there is increased time in the double-support phase for those with diplegia (Hsue et al., 2009a, 2009b) and hemiplegia (Hsue et al., 2009a, 2009b; Wheelwright, Minns, Elton, et al., 1993) as compared to TD peers (Wheelwright, Minns, Law, et al., 1993). Children with hemiplegia have an increased swing time for the paretic limb as compared to the non-involved limb (Wheelwright, Minns, Elton, et al., 1993).

Similar to children with CP, children with DS have decreased stride length and increased step width with increased pelvic motion during gait. Specifically, there is increased amplitude in the ML direction (Kubo & Ulrich, 2006a). Children with DS also exhibit an increase in variability in the AP direction for the COM and head during gait as compared to TD children (Black, Smith, Wu, & Ulrich, 2007). These gait deviations of children with DS continue into adulthood, as adults with DS display increased COM movement and velocity in the ML direction, increased variability, and variable step width (Agiovlasitis, McCubbin, Yun, Mpitsos, & Pavol, 2009b).

The gait deviations of children with ASD have not been investigated as extensively. A 2005 (Vernazza-Martin et al.) study revealed that children with ASD demonstrate increased lateral movement of the trunk, head and shoulders during ambulation as well as increased variability of movement.

Children with CP and with DS have impairments in ROM, strength and sensation, which contribute to impairments in postural control, gait, and GV. Poor biomechanical alignment occurs with impaired and insufficient postural muscle activity during balance

activities, creating deficits in both RPAs and APAs. The decreased ability to produce and manage these adjustments is also carried over into gait, specifically GV. One of the impairments contributing to the impaired weight shifting ability is weakness of the hip abductors.

### **Assessment of impairments of body structures and function.**

This section presents some of the clinically relevant tools to assess the impairments of children with DD. It is important when conducting clinically relevant research that the assessment tools are familiar to clinicians, and are feasible for a clinician to use. The assessment measures presented in the following section were selected because they are both clinically accessible and are reliable and valid measures. The only measures selected that are not as clinician friendly are COP and time to boundary (TTB). The rationales for selecting these two measures are presented below and supported by De Kegel and colleagues (2010) findings that forceplate measures are necessary to complement clinical balance assessment as forceplate measures assess the process of maintaining balance. De Kegel and colleagues (2010) investigated the validity of laboratory (posturography) and clinical measures (balance beam walking, SLST with EO and EC and single limb hopping) in TD children and children with hearing impairments. They found that 4 of the laboratory measures and 2 (balance beam walking and SLST with EC) of the clinical measures were able to discriminate between TD children and those with hearing impairments. Even when the task was the same, maintain SLS, the authors (De Kegel et al., 2010) found that correlations between postural sway and SLST were moderate ( $r = -0.52$ ) for TD children and small for children with hearing impairments ( $r = -0.48$ ).

### ***Balance.***

#### ***Weight bearing symmetry.***

Weight bearing symmetry (WBS) is a static assessment of balance in bilateral stance. The output from the WBS measure is a percentage of weight borne on each lower extremity (Figure 2.2). WBS can be assessed using the WiiFit Plus video game software and Wii Balance Board (WBB) (Nintendo of America, Redmond, WA). The WBB contains four strain gauges and samples at a rate of 60 cycles per second (Iwata). The

WBB is a rectangular board weighing approximately 8 pounds and is 20 inches long by 12 inches wide and 2 inches thick. Little data exists about the reliability and validity of the WBB and WBS test. One report documents poor reliability (ICC= 0.253, 0.270) and validity ( $r= 0.218$ ) of the WBS as compared to the Sensory Organization Test (Gras, Hummer, & Hine, 2009), while others reported when using a standardized foot placement the WBB is reliable (ICC= 0.66 – 0.91) and concurrently valid with a traditional forceplate (ICC= 0.77 – 0.89) measure of balance (Clark et al., 2010). In a pilot study the WBB had reliable (ICC= 0.81) and valid ( $r= 0.65 -0.732$  with Pediatric Balance Score) measurements of SLS for TD children aged 4 to 10 years (Schlueter, Myers, Schick, McAlister, & Ross, 2010). The WBB has the potential to be a clinically useful device, but there is a significant lack of data on the reliability and validity. Thus, for this study a forceplate will also be utilized to measure bilateral static stance.

*Center of pressure and time to boundary.*

COP and TTB are two different measures of postural control that can be calculated from the ground reaction force data. COP is a common method of assessing balance in children with DD (Donker et al., 2008; Ferdjallah et al., 2002; Gepner et al., 1995; Gepner & Mestre, 2002; Kohen-Raz et al., 1992; Kubo & Ulrich, 2006a; Molloy et al., 2003; Rigoldi, Galli, Mainardi, Crivellini, & Albertini, 2011; Rose et al., 2002; Villamonte et al., 2010; Vuillerme et al., 2001) and can be broadly defined as “the center point of force in the x direction and y direction that a participant exerts on a forceplate” (Rose et al., 2002). Data from COP has been demonstrated to be reliable over days of repeated testing (coefficient of variation= 8.5- 13.2%, with <12.5% being acceptable) for children with CP (White et al., 1999) and children with DS (Villamonte et al., 2010). No reliability data for COP measurements could be found for children with ASD. Same day testing of COP variables has also been deemed reliable (Rose et al., 2002). COP velocity and area of a 95% confidence ellipse are two common techniques to describe ground reaction force data, and greater stability is defined when the ellipse is smaller and velocity is greater (Rose et al., 2002).

TTB is a measure of balance in static stance that uses a different theoretical perspective than traditional COP measures; it is considered a non-linear measure of balance. In TTB, in contrast to COP, more time and more variability is desired. TTB can



be broadly defined as the time it would take for the COP to reach the edge of the foot (boundary) if it continued on the same path without changing velocity or direction (van Emmerik & van Wegen, 2002). It is measured in seconds and described in terms of the mean minima and standard deviation. The TTB mean minima is the average time of the minimas, or points, where there is the minimal amount of time to make a correction to the COP due to either a fast COP velocity or the COP approaching the boundaries. The TTB standard deviation is the standard deviation of the mean minimas and is reflective of the number of solutions used to make corrections to maintain balance (Hertel, Olmsted-Kramer, & Challis, 2006; McKeon & Hertel, 2006). Thus TTB data allows analysis of an integration of time and area based on velocity. The more time available and the more solutions available to make corrections to the COP indicate improved postural control. A therapeutic change is increased TTB mean minima and standard deviation. TTB is calculated on actual dimensions of the boundaries of stance, so if there is a larger BOS the boundaries are further apart, allowing an increased area to make corrections to the COP. While a smaller BOS has decreased area, it does not correlate that there is decreased time to make corrections. This is important to consider in children with DD, because children with different DD have different BOSs. Children with DS generally stand with a wide BOS, while children with spastic diplegia in crouch posture would have smaller BOSs, though theoretically they may have similar TTB values.

Like COP data, TTB data can be analyzed in AP direction and ML directions with EO and EC. TTB has not been tested in young TD children nor in children with DD, but has been assessed in adults with Parkinson's disease (van Wegen, van Emmerik, Wagenaar, & Ellis, 2001), patients with chronic ankle instability (Hoch & McKeon, 2011; McKeon & Hertel, 2008; McKeon et al., 2008), women with multiple sclerosis (Van Emmerik, Remelius, Johnson, Chung, & Kent-Braun, 2010), and adolescent females with scoliosis (Gruber et al., 2011). The TTB measure has a history of greater sensitivity to change and use with balance training programs (McKeon et al., 2008). The closest measures to TTB found in CP balance literature are measures of regularity of sway (Donker et al., 2008) and likelihood of COP to change direction (Rose et al., 2002). Similar to TTB, the measure of regularity of sway is increased in those with neurological impairments, and



children with CP have been found to have more regular postural sway (less variable) than their TD peers (Donker et al., 2008; Dusing & Harbourne, 2010; Harbourne et al., 2010).

There is limited data on the reliability and validity of TTB, and none exists for children. For healthy college age adults, the reliability in SLS is variable (ICC= 0.34 to 0.87), (Hertel et al., 2006), but improves with dual limb stance (ICC= 0.53 to 0.97), (Wheat, Haddad, & Scaife, 2012). The TTB measures in SLS did correlate to traditional COP measures ( $r = -0.90$  to  $-0.11$ ) for this same population (Hertel et al., 2006). Due to the nature of balance impairments in children with DD, TTB assessment will be performed in dual limb stance.

#### *Timed up and go.*

The Timed Up and Go (TUG) is a dynamic measure of balance and gait. The TUG is a test of functional mobility and involves the participant rising from a chair, ambulating 3 m and returning to the seated position. The time to complete the task is recorded in seconds. In TD children, aged 3 to 9 years, the TUG demonstrated excellent within session (ICC= 0.80- 0.89) and test-retest reliability (ICC= 0.83), (Williams et al., 2005). The TUG also demonstrated good response stability for children aged 3 to 9 years (ICC= 0.89) for TD children (Williams et al., 2005). For children with CP (5 to 12 years, GMFCS I-IV), the TUG demonstrated good concurrent validity with the Berg Balance Scale ( $r_s = -0.88$ ) and the Functional Reach Test ( $r_s = -0.77$ ), (Gan, Tung, Tang, & Wang, 2008). It is also concurrently valid with the Timed Up and Down Stairs ( $r_s = 0.78$ ), (Zaino, Marchese, & Westcott, 2004). There is excellent test-retest reliability (ICC= 0.99) for children with CP, aged 3 to 19 years, GMFCS levels I-IV (Gan et al., 2008; Williams et al., 2005). For children with DS the TUG had excellent inter- and intra-rater reliability (ICC= 0.99, 0.86) and was found to be concurrently valid with the Standardized Walking Obstacle Course (Held, Kott, & Young, 2006). There is no reported reliability or validity data on the TUG for children with ASD.

#### *Single limb stance time.*

The length time a child maintains SLS is a common clinical measure of balance. The child is asked to stand on the preferred limb with the opposite limb's knee flexed to 90° and the hip in neutral. The time maintaining the position with the hands on the hips is

recorded. Testing is completed when 30 seconds is reached, the foot drops or the hands come off the hips (Atwater et al., 1990). Single limb stance time (SLST) is reliable and valid for children who are TD and those with CP between the ages of 4 and 15 years. Concurrent validity was demonstrated with the Timed Up and Down Stairs ( $r_s = -0.77$ ) for children with CP and those TD (Zaino et al., 2004). High inter-rater reliability ( $r_s = 1.00$ ) was reported for TD children with EO (Atwater et al., 1990). For children with DS SLST was reported as one of the few reliable tests of balance (Villamonte et al., 2010).

### ***Strength of hip abductors.***

Muscle weakness is a known impairment for children with CP and DS. Hand-held dynamometry is one way to assess muscle strength. The hip abductors are a muscle group commonly cited as being weak for children with CP (Wiley & Damiano, 1998), and necessary to facilitate and control weight-shifting during ambulation (Metaxiotis et al., 2000). The strength of the hip abductors are predictive of gait (Metaxiotis et al., 2000), balance (Lowe et al., 2004) and functional abilities (Eek & Beckung, 2008; Ross & Engsberg, 2007). Hand-held dynamometry is a reliable test of muscle strength of the hip abductors (ICC= 0.89-0.97) for children with CP (Berry, Giuliani, & Damiano, 2004; Taylor, Dodd, & Graham, 2004) and those with DS (ICC= 0.94) (Mercer & Lewis, 2001). There are established normative values in TD children (Eek, Kroksmark, & Beckung, 2006).

### ***Gait velocity.***

GV is a commonly cited outcome measure in studies of children with CP following surgery and specific interventions (Paul, Siegel, Malley, & Jaeger, 2007). GV increases following lower extremity strengthening programs for children with CP (Damiano, Kelly, & Vaughn, 1995; Eagleton, Iams, McDowell, Morrison, & Evans, 2004; Engsberg, Ross, & Collins, 2006; Lee, Sung, & Yoo, 2008). Reporting and assessment of GV varies; it can be calculated by recording the time it takes to ambulate a predetermined distance and dividing the distance by the time, and then it can be normalized based on height or leg length. In this study GV was calculated simply as

$$GV = \frac{\text{distance}}{\text{time}}, \text{ where the distance is in meters and time in seconds.}$$

## **Activity Limitations and Participation Restrictions**

Children with CP have limitations in their ability to perform activities of daily living (Kerr, McDowell, & McDonough, 2007), general limitations in activities (Kerr, Parkes, Stevenson, Cosgrove, & McDowell, 2008) and in participation (Lepage, Noreau, Bernard, & Fougereyrollas, 1998; Majnemer et al., 2008). It is important to adolescents with CP to participate with their peers and have a choice in activities (Shikako-Thomas et al., 2009). While children with CP are participating and enjoying leisure pursuits, these pursuits tend to be lower skill-based and activity based (Majnemer et al., 2008). A study of Australian children with CP demonstrated that they participated in leisure pursuits that were less formal than their TD peers and with lower frequencies and intensities (Imms et al., 2008).

The literature suggests that though children with CP are integrated into the general education classroom, they continue to have difficulty engaging and participating with their TD peers (Lawlor, Mihaylov, Welsh, Jarvis, & Colver, 2006; Llewellyn, 2000; Nadeau & Tessier, 2006; Richardson, 2002; Schenker, Coster, & Parush, 2006). Children with CP (specifically females) had fewer reciprocated friendships, exhibited fewer sociable/leadership behaviors, and were more isolated and victimized by their peers than their classmates without a disability (Nadeau & Tessier, 2006). They also will frequently initiate more interactions with adults than their peers (Richardson, 2002).

The activities and participation of children with DS are more informal, sedentary, and less spontaneous (Wuang & Su, 2012), similar to children with CP. Children with DS also participate in less moderate to high intensity physical activity (Shields, Dodd, & Ablitt, 2009; Whitt-Glover, O'Neill, & Stettler, 2006). Shields (2009) found that 58% of children with DS did not meet the recommended amount of physical activity, which is a significant concern given the high risk of obesity for children and adults with DS. Some barriers identified to participation for children with DS were the impairments of body structures and functions associated with DS, competing family responsibilities, decreased physical and behavioral skills, and a lack of accessible programs (Barr & Shields, 2011).

Similar to children with CP and with DS, children with ASD also have impairments in participation and activities. The more common activities reported for children and adolescents with ASD are sedentary in nature, include watching television

and playing internet and computer games (Brewster & Coleyshaw, 2011). One study reported a physical activity, playing outside, though it was reported to be a solitary activity (Brewster & Coleyshaw, 2011). Based on the diagnosis of ASD, one would anticipate that the activities and participation of a child with ASD be more solitary in nature. While solitary activities do not have to be sedentary, children and adults with ASD choose activities and leisure pursuits that are sedentary (Brewster & Coleyshaw, 2011; Garcia-Villamisar & Dattilo, 2010; Todd & Reid, 2006). These activities can be modified with intervention. Following intervention adults with ASD reported increased satisfaction and decreased stress (Garcia-Villamisar & Dattilo, 2010), and these continued with increased physical activity (Todd & Reid, 2006). In a 2010 (Solish, Perry, & Minnes) study parents reported that their children with ASD participated in less social and recreational activities than TD peers and that leisure and recreational activities were more often performed with adults. Children with ASD were significantly less likely to have a best friend as compared to TD children and children with an intellectual disability (Solish et al., 2010). There is a definitive impairment in the activities and participation of children with ASD that impacts both socialization with peers and physical activity.

While there are significant barriers to participation for all children with DD, there are supports that can enhance participation. Majnemer and colleagues (2008) found that involvement in rehabilitation services enhanced the participation of children with CP. Barr and Shields (2011) identified four themes that increased participation for youths with DS: the role of the family; opportunity for social interaction; structured accessible programs that accommodate children with DS and a child who was determined and physically skilled. There is a clear trend that the physical abilities of children with DD can act as both an obstacle and a support to participation. It is the responsibility of the rehabilitation professional to consider activities and participation when designing and implementing intervention programs for children with DD, which is supported in the guidelines of O'Neil and colleagues (2006).

#### **Assessment of activity limitations: Activities Scale for Kids.**

The ICF defines activity as the execution of a task or activity by an individual and participation as the involvement in society, community and family (World Health Organization, 2001). Harvey's (2008) systematic review based on ICF definitions

reported the two best measures of activity limitations were the Activities Scale for Kids (ASK) and the GMFM. The GMFM has a reported ceiling effect for high-functioning children with CP (Shumway-Cook et al., 2003), and thus may not be the most sensitive to change following intervention.

The Activities Scale for Kids, performance version (ASKp) is a measure of activities performed by the child in the past 1 week (Young et al., 1996; Young et al., 1995). It is a self-report questionnaire developed for children aged 5 to 15 years with musculoskeletal disorders, and is completed by the child, though it can be completed by a parent if necessary (Young et al., 1996). There are 30 items that assess activities in three locations: home, school and the community. The ASKp is reliable (ICC= 0.97), (Young et al., 1995) and valid ( $r= 0.81-0.92$ ), (Young, Williams, Yoshida, & Wright, 2000). It has an established minimum clinically important difference of 1.73 standard deviation units (Young et al., 2000). The ASKp has been used with children with CP (Morris, Kurinczuk, & Fitzpatrick, 2005; Morris, Kurinczuk, Fitzpatrick, & Rosenbaum, 2006; Palisano, Copeland, & Galuppi, 2007), spina bifida (Smith, Owen, Fehlings, & Wright, 2005), juvenile arthritis (Stephens et al., 2007), fractures (Boutis et al., 2007; Epps, Molenaar, & O'Connor D, 2006; Plint, Perry, Correll, Gaboury, & Lawton, 2006; Rabinovich, Adili, & Mah, 2005), scoliosis (Wai, Young, Feldman, Badley, & Wright, 2005), and bone tumors (Pakulis, Young, & Davis, 2005).

### **Balance Training**

Balance training for children with CP is one of the few therapy intervention categories with literature to support use during clinical practice (Anttila et al., 2008). This review article (Anttila et al., 2008) included studies with balance training as part of physical therapy interventions, in addition to balance training only interventions. Though there is evidence to support use in practice, the literature base is extremely small, particularly just for studies that focus on balance training. Four studies were found that investigated balance training alone for children with CP (Hartveld & Hegarty, 1996; Ledebt et al., 2005; Shumway-Cook et al., 2003; Woollacott et al., 2005) and none for children with ASD or DS. The aforementioned studies utilized computerized balance training (CBT), in contrast to more clinical, or “traditional” balance training. CBT has been demonstrated to be effective in TD children (Sveistrup & Woollacott, 1997).

Traditional balance training activities may include passive and active weight shifting, static and dynamic SLS activities, perturbations, performing activities on an unstable surface and using a narrow BOS (Westcott, Murray, & Pence, 1998). These activities are combinations of both RPA and APA. Other traditional balance training interventions such as the therapist applying a perturbation are dependent on RPA, though it has been suggested that this is not an effective intervention to improve postural control (Dusing & Harbourne, 2010). Many CBT interventions are also dependent on RPA, applying a measurable perturbation through the movement of the forceplate and thus to the child. APA interventions traditionally include having the participant move out of the BOS, while CBT may have participants practice with visual feedback while moving their COP to specified targets. Recently Dusing and Harbourne (2010) suggested that postural control training should be embedded within activities and not specifically addressed through perturbation challenges. Allowing children with DD the opportunities to explore new movements without an external stimulus may increase the amount and variability of available movement strategies, thus increasing the complexity.

### **Computerized Balance Training Protocols**

Of the four studies using CBT for children with CP, two of the studies utilized RPA through a mobile forceplate perturbation-training program (Shumway-Cook et al., 2003; Woollacott et al., 2005) and two utilized APA with a visual feedback based weight-shifting protocol (Hartveld & Hegarty, 1996; Ledebt et al., 2005). The intensity and frequency of the intervention protocols varied. Both RPA studies (Shumway-Cook et al., 2003; Woollacott et al., 2005) used five consecutive training days, with 100 total perturbations per day provided by a moveable force-platform at 4 to 6 per minute at a rate of 12 to 24 cm/s. Rest breaks were provided every 20 to 25 perturbations. In Hartveld and Hegarty's (1996) study the subjects were advised to practice multi-directional weight shifting, with actual times ranging from 11 to 48 minutes per day between 7 and 61 days. Weight shifting occurred on a Compex board, a moveable platform that detected COP direction, and was integrated with their home computer to manipulate a character in a video game (Hartveld, Hegarty, & Blurton, 1996). A stable force platform using specified target areas was utilized by Ledebt and colleagues (2005) for 30 min sessions 3 times per week for 6 weeks. Sessions consisted of subjects keeping their COP within a target area

on screen for stability training, and then dynamically moving their COP in successive targets of clockwise, counterclockwise, random pattern, or lateral weight shifting. The COP target area was represented on a screen as a red dot and the child was asked to keep the dot in the appropriate square. The children with CP in these studies had spastic diplegia, spastic right, and left hemiplegia and GMFCS levels I and II, aged 5 to 16 years.

Improvements in balance and postural control following CBT for children with CP were reported from the four studies (Hartveld & Hegarty, 1996; Ledebt et al., 2005; Shumway-Cook et al., 2003; Woollacott et al., 2005). The perturbation protocols reported decreased COP sway area and time to stabilization immediately ( $p < 0.01$  for both), and 30 days post intervention compared to pretest ( $p < 0.01$ ,  $< 0.05$  respectively), (Shumway-Cook et al., 2003). Following perturbation training children with hemiplegia (paretic leg only) and diplegia CP had no change or decreased onset latency for gastrocnemius and tibialis anterior. The gastrocnemius also had decreased contraction amplitude for children with hemiplegia and diplegia CP and decreased or no change in contraction amplitude asymmetry for children with hemiplegia CP. Decreased contraction amplitude of tibialis anterior was also reported following perturbation training for children with diplegia CP (Woollacott et al., 2005).

One visual feedback weight shifting protocol (Ledebt et al., 2005) reported COP amplitude during quiet stance significantly decreased ( $p = 0.039$  forward sway,  $p = 0.026$  backward sway), while during dynamic stance COP amplitude increased ( $p = 0.002$  forward,  $0.027$  backward,  $0.021$  non-paretic side). There were no changes towards the paretic side for quiet or dynamic stance, and changes occurred primarily in the AP direction more than the ML direction (Ledebt et al., 2005). The other visual feedback weight shifting study (Hartveld & Hegarty, 1996) used a single subject design and presented data through visual analysis of the data trends. They reported SLST had a significant trend of increased time for one subject and a small trend increase for the other subject. The other two subjects were assessed individually for stance time with knees together and stance time with feet 5 cm apart; both subjects demonstrated trends towards increased time in these positions (Hartveld & Hegarty, 1996).

Gait significantly improved for children with hemiplegic CP immediately following weight shifting CBT. Step length when the non-paretic side was swinging



forward significantly increased ( $p= 0.017$ ), while step length asymmetry significantly decreased ( $p= 0.021$ ) immediately following CBT (Ledebt et al., 2005).

Only Shumway-Cook and colleagues' (2003) study utilized a functional measure, the GMFM (Russell et al., 2002). Immediately post CBT 4 of the 5 subjects demonstrated either no change or improvements on dimension D. Improvements ranged from 2.94% to 11.76% increases for both children with hemiplegia and diplegia, and the authors (Shumway-Cook et al., 2003) cited a ceiling effect as a possibility for the small improvements. One subject with diplegia did demonstrate a 2.87% decline in score immediately post CBT. The authors offered no explanations for the decrease in score.

### **Summary**

CBT for school-age children with hemiplegic and diplegic CP is a promising new intervention to improve balance. Three of the studies (Ledebt et al., 2005; Shumway-Cook et al., 2003; Woollacott et al., 2005) reported specific improvements in balance, gait and muscle activation patterns, while 2 participants of one study (Hartveld & Hegarty, 1996) demonstrated trends towards improved balance. Immediate changes in balance, gait, and muscle activation patterns were observed (Ledebt et al., 2005; Shumway-Cook et al., 2003; Woollacott et al., 2005), with effects continuing at 30 days post for balance and some muscle activation patterns for children with CP (Shumway-Cook et al., 2003; Woollacott et al., 2005). Balance measures across the studies reflected improvements in both APA (quiet dual limb stance, SLST) and RPA (area and time to stabilization following perturbation). No single study assessed both APA and RPA. Studies consistently used one type of balance assessment, APA or RPA, which then correlated with the intervention protocol.

The specificity of CBT may produce more effective and lasting changes in balance than traditional balance training therapy (static and dynamic SLS activities, therapist applied perturbations, unstable surfaces and using a narrow BOS (Westcott, Murray, et al., 1998)). Training and assessments utilizing APA or RPA alone may be the key to improvements following CBT, and reflective of a specificity of testing and training bias. None of the studies reviewed directly compared CBT to traditional balance training therapy, though improvements in components other than balance reflect the global effects of CBT. Positive changes were reported in gait parameters and EMG recordings post



CBT (Ledebt et al., 2005; Woollacott et al., 2005). CBT also demonstrated improvements in a clinical measure of function (GMFM) for children with CP (Shumway-Cook et al., 2003). The accumulation of these changes may lead to increased function and participation for children with CP. CBT appears to be an effective method of improving balance and muscular control in children with CP, but further research is needed to specifically investigate multi-directional weight shifting training. To our knowledge there were no published studies investigating CBT alone for children with DS or ASD.

### **Technology and Body Functions and Structures**

With the rapid advances in technology there are many new approaches to providing interventions for patients. As previously discussed CBT may be effective at improving balance in children with DD. All of the previously discussed studies utilized forceplates to perform CBT in a manner that may not have been engaging and enjoyable to children. Balance training has the potential to be an engaging and enjoyable intervention through the use of technology that immerses the child in tasks, such as virtual reality (VR) and gaming (Brumels et al., 2008). VR and gaming technology use similar models to engage the participant, but there are distinct differences. The use of these two technologies on body functions and structures and participation will be discussed in the following sections.

#### **Virtual Reality**

VR can be broadly defined as computer simulated environments utilizing visual and haptic feedback that completely immerses the participant. One of the primary advantages of VR is the immersion; through the use of displays, headgear, body suits and other peripherals the participant is virtually transported into an alternate reality where they can receive different sensory feedback. Applications of VR are being used in rehabilitation in multiple areas, from the elderly at risk for falls (Virk & McConville, 2006), to persons post stroke (Walker et al., 2010), children with CP (Brien & Sveistrup, 2011; Golomb et al., 2010; You et al., 2005), children with DS (Hovorka & Virji-Babul, 2006), and adults with DD (Yalon-Chamovitz & Weiss, 2008). Balance training is only one aspect of VR rehabilitation; VR has been used for strengthening and ROM (Bryanton

et al., 2006), reaching (Chen et al., 2007), spatial concepts (Akhutina et al., 2003) and increased physical activity (Yalon-Chamovitz & Weiss, 2008).

In a true VR system participants are unable to ignore visual input and will change their postural orientation in response to the changing visual field (Keshner & Kenyon, 2009). During use of VR, healthy individuals have an increase in postural sway that is similar to non-VR EC stance (Horlings et al., 2009). Though an increase in postural sway has been reported and considered to be a negative consequence of using VR, there is no documentation how long the increased postural sway occurred, or if it carried over when participants leave the VR environment (Horlings et al., 2009). Adults with traumatic brain injury reported increased balance confidence following a VR balance training intervention of 50 minutes, 3 times per week for 6 weeks (Thornton et al., 2005). While balance abilities were not assessed, the focus groups' responses following VR intervention reflected improved balance during activities of daily living. The focus groups also reported that VR was more enjoyable and interesting than traditional therapy (Thornton et al., 2005). In a recent intensive study using VR adolescents with CP significantly increased their balance and distance walked in 6 minutes, though the authors did not report if the participants found VR enjoyable or engaging (Brien & Sveistrup, 2011).

The enjoyable and novel factor of VR rehabilitation has been demonstrated in children with CP and adults with DD. VR exercises were reported to be more fun and enjoyable compared to traditional ROM and strengthening exercises for children with CP (Bryanton et al., 2006). Parents reported their children appeared more motivated and use of a computer increased the likelihood that their child would complete the home exercise program (Bryanton et al., 2006). The adults with DD found VR enjoyable, engaging and challenging, and the authors reported that some participants asked to continue with the VR intervention after the study concluded (Yalon-Chamovitz & Weiss, 2008). Increased compliance, finger ROM, and bone density occurred following VR intervention at home in children with CP (Golomb et al., 2010). Adolescents with hemiplegic CP were given an in-home VR system to improve arm and hand function and were found to practice an average of 20 minutes per day. Neuroplastic changes have been demonstrated following VR therapy for the upper extremity (Golomb et al., 2010; You et al., 2005), and it

appears that VR therapy is a promising new intervention for children with hemiparetic CP. Clearly more research needs to be performed to determine the appropriate intensity and frequency of intervention for upper and lower extremity rehabilitation.

One of the primary issues with VR research is that the term “virtual reality” has such a broad definition that many researchers are calling their systems VR, when in fact they are visual feedback systems that do not completely immerse the participant. While visual feedback systems are computer generated they do not provide the sensory feedback of a true VR system. Visual feedback systems more closely resemble video game systems, such as the Nintendo Wii or PlayStation EyeToy. While VR is a promising technology intervention for children with DD there is still much research to be done about clearly defining what is VR and how it can be best applied to children with DD. Reviews of VR therapy in the pediatric populations confirm that VR interventions are promising (Laufer & Weiss, 2011; Parsons, Rizzo, Rogers, & York, 2009).

### **Gaming**

In contrast to VR, video game (VG) systems are primarily visual feedback systems and are not considered immersive. Researchers have turned from traditional VR systems to VG technology as a way to translate research into the clinic. VG systems are a fraction of the cost of custom designed VR systems. Traditional VGs are played with the participant seated using a handheld device to play the game. Newer VG systems, such as the PlayStation Eye-Toy, Nintendo Wii, and X-box Kinect, utilize motion capture (PlayStation and Kinect) and accelerometry (Wii) to play games. Nintendo has even developed the WBB, which captures ground reaction force data and utilizes this data to play the games. With the advent of these types of systems VG technology has many more applications to rehabilitation. Feasibility and efficacy studies utilizing these systems are being conducted (Andrysek et al., 2012; Berg et al., 2012; Brumels et al., 2008; Deutsch et al., 2008; Eissenzopf & Salem, 2010; Flynn, Palma, & Bender, 2007; Liu et al., 2009a; Nelson, Pladera, Seidl, & Furze, 2010; Wang et al., 2011).

One of the major uses of VG technology in the medical field is to increase physical activity in adolescents. With the rate of obesity rising in children, the use of physical activity based VGs provides a unique opportunity to engage children. Specifically, the Nintendo Wii has been found to increase energy expenditure while

playing VGs compared to playing traditional seated VGs (Graves, Stratton, Ridgers, & Cable, 2007; Graves, Stratton, Ridgers, & Cable, 2008; Lanningham-Foster et al., 2009). A caveat to the studies is that while the children are expending more energy than playing traditional VGs, the amount of energy expended is not equivalent to actually playing the sport portrayed (Graves et al., 2007; Graves et al., 2008). While this research has been performed on TD children, it certainly applies to children with DD who are frequently at a greater risk of obesity.

VG technology has been widely applied to balance training. Hartveld and colleagues' (1996) early study utilized a custom-designed VG for balance training for children with CP, and reported trends of improved balance in SLST and other challenging dual limb stance positions. Since that study there have been other custom designed VG for balance training for adults with neurological impairments (Betker et al., 2006) and use of commercially available VG systems for balance training in healthy adults (Brumels et al., 2008). Both groups demonstrated improvements in balance for adults with neurological impairments in dynamic abilities and number of falls (Betker et al., 2006), while the healthy adults decreased postural sway in the sagittal plane (Brumels et al., 2008). It can be hypothesized that the movements required to complete the VG training required more precise movements in the sagittal plane than the traditional exercises. These forms of balance training also appeared to have greater motivation and attention (Betker et al., 2006) as well as being more enjoyable and engaging than traditional balance training (Brumels et al., 2008).

The research utilizing VG technology as balance training has focused on Nintendo's Wii and WiiFit, as systems such as Sony's PlayStation Eye-Toy are no longer available. The Wii was used successfully in training an adolescent with CP (Deutsch et al., 2008), adolescents with lower limb amputations (Andrysek et al., 2012), and children with DS (Berg et al., 2012; Wuang et al., 2011). Following use of the Wii and WiiFit improvements have been demonstrated in postural sway, WBS, visual perceptual processing, APAs, onset of the tibialis anterior and manual dexterity (Andrysek et al., 2012; Berg et al., 2012; Deutsch et al., 2008; Liu et al., 2009a; Wuang et al., 2011). The adolescent with CP enjoyed playing the games and having the opportunity to engage with a TD peer during game play (Deutsch et al., 2008). A unique aspect of the use of VGs as

a part of rehabilitation therapy is that these commercially available systems can be incorporated into home exercise programs and may provide new opportunities for children with a disability to participate with their TD peers in a physical activity.

While there is limited research on the use of VG technology on postural control, the existing evidence is positive and demonstrates that VGs are not harmful and may be a motivating intervention for clients. More research is needed investigating intensity and frequency of VG interventions for children with DD. Future research needs to clearly delineate which VG system is utilized and which VGs are played and at which settings. It is important to clarify that VGs are a tool for the clinician and are not meant to replace a therapist. Potential limitations of VG use as a therapeutic tool must also be addressed, including emotional response of not scoring well, falling off the WBB, overuse injuries and the risk for seizures.

Minimal research exists using VR and VG for children with DD and postural control. The use of new technology for interventions with children with DD may increase motivation when compared to traditional interventions and may be a new way to encourage participation in therapy sessions for a reluctant child. VG technology has the potential to be a fun and motivating home program.

### **Summary**

Postural control develops over time, especially with respect to the sensory systems required to maintain balance. Much is known about the timeline of development for sensory systems for TD children, but less is known about the timeline of development for children with DD. Children with DD vary greatly in their balance abilities as compared to their TD peers. Variations have been demonstrated between children who are TD and those with CP, DS, and ASD in their postural control and sway. Children with CP and those with DS sway more often and those with CP sway at more regular intervals than their peers, which is indicative of impaired postural control. Variability and complexity in postural sway is necessary for the maintenance of balance during challenging activities.

There are many theories why children with DD may have less adaptability in their balance, including decreased ROM and strength, poor biomechanical alignment, and impairments in sensation. It is likely a combination of these theories explain decreased

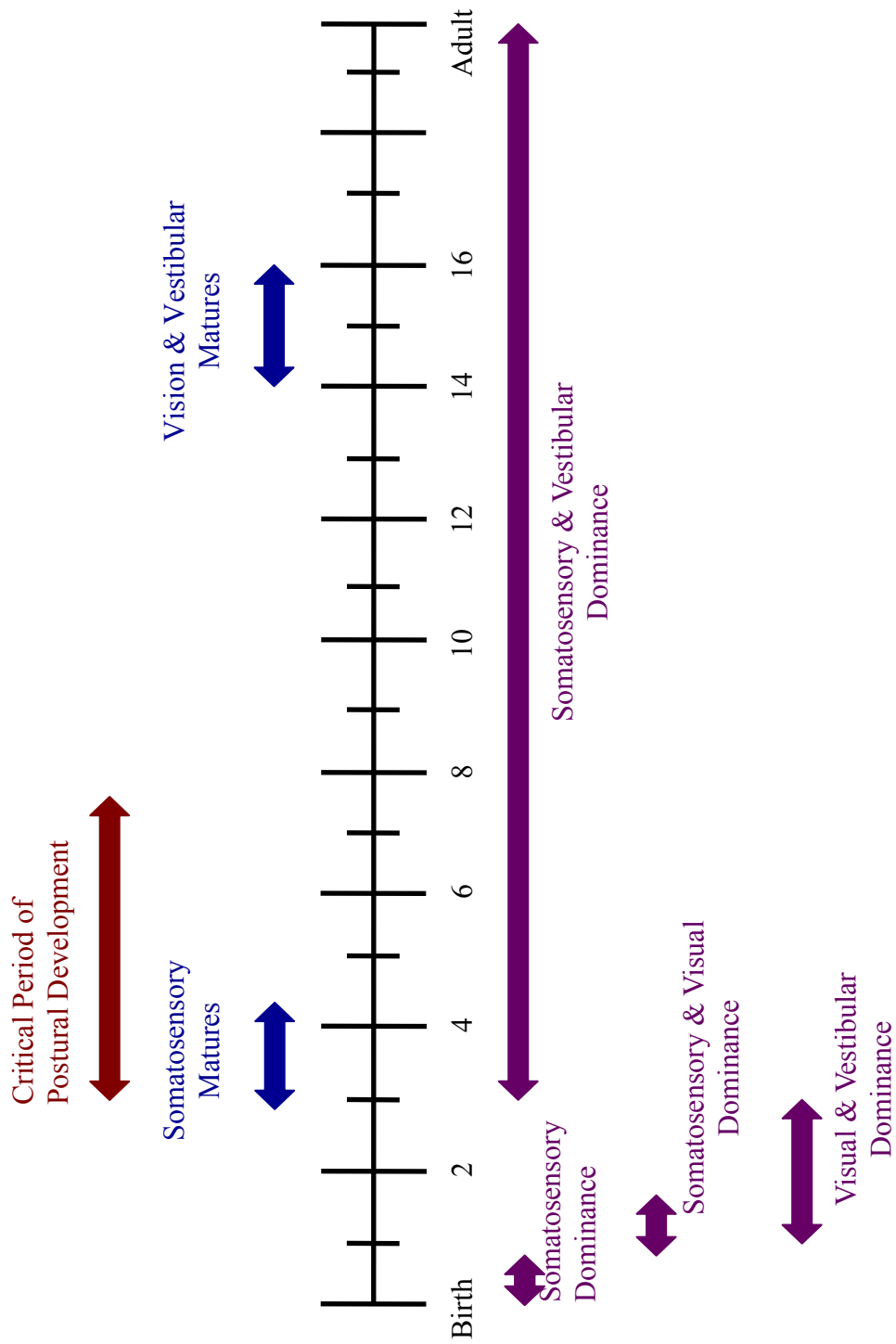
postural control of children with DD. Good postural control is necessary for efficient gait. One theory of why children with CP have a slower GV is that they have an impaired ability to rhythmically weight-shift (Liao et al., 1997). Weight-shifts are crucial to gait and if there is an impaired ability to shift it will decrease the GV (Liao et al., 1997). Targeting weight shifting through intervention may increase GV in children with DD, making them better able to participate with their peers and perform activities of daily living.

Providing a weight-shifting intervention through a novel stimulus, such as VR or VG technology may improve interest and participation in the intervention. While some studies have focused on AP weight shifting, multi-directional weight shifting emulates the movements required for smooth and efficient gait and activities of daily living. Very rarely are straight plane movements utilized in activities and thus intervention protocols should include multiple planes. While the literature is promising on the use of balance training in children with DD it has not evaluated the effect on activities and participation. Interventions should be provided that have effects on activities and participation, especially for children with DD.

This series of studies was designed to incorporate components from multiple studies in the balance training literature for children with DD with the use of VG technology. The novelty of these studies was in the evaluation of balance, strength, GV and activities prior, during and after the multi-directional balance training program that was conducted under therapist supervision at the participant's home. By combining elements from multiple perspectives, this study was designed to elicit information about how a multi-directional VG based balance training program changes the entire child with DD from body structures to activities.

Figure 2.1

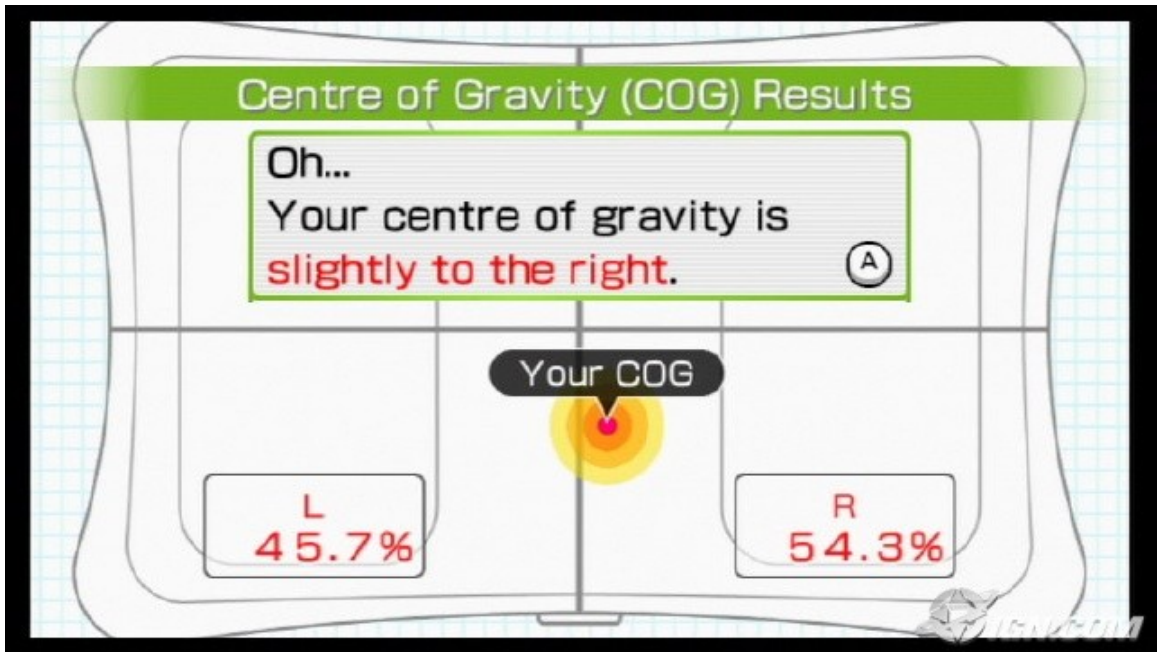
*Milestones of Balance Development in Typically Developing Children by Year*



\* Known transitional periods of postural control

Figure 2.2

Output from Wii for Weight Bearing Symmetry





## Chapter Three: Use of Wiifit™ on Balance and Function in Children with Cerebral Palsy: A Pilot Study

### Introduction

Children with cerebral palsy (CP) are known to have balance impairments, with smaller anticipatory adjustments (Girolami, Shiratori, & Aruin, 2011; Tomita et al., 2011; Westcott, Zaino, et al., 1998; Zaino, 1999), larger responses to perturbations (Rose et al., 2002; Shumway-Cook et al., 2003) and increased postural sway velocity and area compared to typically developing (TD) peers (Donker et al., 2008; Rose et al., 2002). These impairments challenge the child with CP's ability to quickly adapt to threats to balance. The balance threats that occur during physical activities may make children with CP feel unstable, thus they are more likely to choose activities that are more sedentary in nature (Imms, 2008). The participation literature suggests that children with CP tend to choose leisure activities that are unstructured, with limited social interaction from their peers and sedentary (Imms et al., 2008; Kerr et al., 2007; Kerr et al., 2008; Law et al., 2006; Lawlor et al., 2006; Llewellyn, 2000; Majnemer et al., 2008; Nadeau & Tessier, 2006; Richardson, 2002; Schenker et al., 2006). Sedentary activities will do little to assist the child with CP in improving their balance abilities, creating a cycle of inactivity and limited participation with their peers.

Children with CP may also limit their participation and activities because of slower gait velocities (GV) than their TD peers. Slower GV have been related to a decreased ability to rhythmically laterally weight shift (Liao & Hwang, 2003). The slower GVs of children with CP are not only explained by their balance abilities, but weakness in multiple muscle groups of the lower extremities, poor biomechanical alignment and decreased range of motion (Burtner, Woollacott, & Qualls, 1999; Lowes et al., 2004). Each of these components will affect the child's ability to participate as well as their GV. Recent participation literature supports the findings that children with CP who have greater physical abilities, meaning fewer impairments of their body structures and function, have higher intensities of participation (Imms et al., 2008; Majnemer et al., 2008).

There exist few studies that have evaluated multiple components of body structures and function as well as participation and activities for children with CP. Many

studies addressed the child's balance abilities, but did not examine strength or GV (Burtner et al., 1998; Burtner et al., 2007; Burtner et al., 1999; Cherng et al., 1999; Girolami et al., 2011; Nashner et al., 1983; Shumway-Cook et al., 2003). In turn, most research about the strength of children with CP did not address their balance abilities (Damiano, Arnold, Steele, & Delp, 2010; Damiano et al., 1995). Recently combining individual components such as strength, balance or GV with the child's participation and activities has been documented in the literature (Kerr et al., 2007; Kerr et al., 2008). While the rehabilitation literature continues to increase in the use of multiple components of the ICF model, there are few that investigate multiple types of body structures and function in conjunction with activities and participation. This is especially prevalent in the balance literature for children with CP.

Using the ICF model this study sought to examine the child with CP from multiple perspectives including balance, strength, GV and activities using Valvano's (2004) activity-based intervention model for a multi-directional balance training intervention. The majority of technology based balance-training interventions for children with CP are neither activity based, nor clinician friendly. With the advent of gaming systems such as the Nintendo Wii and WiiFit the possibilities for using technology as a balance training intervention in the clinic, or home, became feasible (Deutsch et al., 2008). The purpose of this study was to explore the use of a therapist directed, video game based, multi-directional balance training intervention on the balance, strength, GV and activities of children with CP in the home environment.

## **Methods**

### **Research Design**

This study utilized a replicated single-subject non-concurrent multiple baseline design across participants and variables. A multiple-baseline across participants design allows the investigator to demonstrate the effect of applying an intervention to a behavior in which it is not desirable to reverse the behavior (Kennedy, 2005). A multiple baseline design across participants utilizes a minimum of two participants and the intervention is applied to the first participant and then systematically applied to the subsequent participants based on pre-determined criteria all following a baseline phase. In this study

a predetermined baseline length of 3, 4 or 5 sessions was randomly assigned to the participants.

### **Approval, Consent & Assent**

Approval for this study was obtained from the University of Kentucky Medical Institutional Review Board with a full review. Informed consent was obtained from the parent or guardian prior to beginning the study and child assent was also obtained. Forms for informed consent and child assent are provided in Appendix A.

### **Participants**

Participants were recruited as a convenience sample from local therapy agencies and school districts throughout Kentucky. Fliers were distributed to therapists at agencies and school districts and asked to pass along to potential participants. To increase the participant pool, participants were also recruited from a pediatric rehabilitation center in Rochester, New York. Therapists employed at the center identified potential participants and were provided with the contact information for the primary investigator. All participants were compensated \$80 for their participation in the study. One participant won their own Nintendo Wii™ and WiiFit™ from a random drawing of five participants.

#### **Inclusion Criteria**

Participants were included for this study if they had a diagnosis of hemiplegia or diplegia CP, and were between the ages of 5 and 10 years at the beginning of the study, and had a classification on the Gross Motor Function Classification System (GMFCS) at level I, II or III (Palisano et al., 1997; Palisano et al., 2008). The participants had to be able to stand without support for 3 minutes and follow two-step directions. Participants also had to be free from an ear infection in the past 6 weeks (Casselbrant et al., 2000), have no known hearing impairment per parent report, and normal or corrected to normal vision. Participants were not to have undergone spinal or lower extremity surgery in the past 3 months, as this is known to significantly affect gait abilities (Gage, 1990).

#### **Exclusion Criteria**

Participants were excluded from this study if they had a diagnosis of quadriplegia, athetoid, or hypotonia CP. Those with uncontrolled seizure disorders were excluded, as

were those who have had a history of an ear infection not healing in 3 months time, or those not meeting the inclusion criteria.

### **Participant Demographics**

A summary of the participant characteristics, including a schedule of therapies the participants were currently receiving, is presented in Table 3.1. Two males (7 years) with spastic diplegia CP (GMFCS I, II) and one male with spastic left hemiplegia (8 years, GMFCS I) participated from Rochester, NY. Two females from Lexington, KY participated; one with spastic left hemiplegia CP (10 years, GMFCS I) and one with spastic diplegia (9 years, GMFCS II).

### **Assessment Tools and Outcome Measures**

Reliability and validity of the assessment tools and outcome measures are reported in the previous chapter, and are briefly summarized below. All assessment tools were administered at the participants' homes. The participant was in barefeet and without assistive device.

#### **Balance**

##### ***Weight bearing symmetry.***

Weight bearing symmetry (WBS) was assessed using the WiiFit™ Plus software and Wii balance board (WBB) from the Nintendo Wii™ gaming console (Nintendo of America, Redmond, WA). Participants stood on the WBB in a bilateral stance that was comfortable and maintained this position for 6 seconds with eyes open (EO). Prior to administration the software displayed a 3 second countdown, and during testing a green light was displayed on the television as a visual focus. Figure 3.1 presents the graphic displayed at the end of administration with the WBS data. The percentages for both limbs were recorded. To increase the reliability of WBS with the WBB the distance between the medial aspect of the first metatarsal heads and medial malleoli borders were recorded at the first visit and kept constant between sessions.

##### ***Center of pressure and time to boundary.***

Ground reaction force data was assessed on an Accusway forceplate (AMTI, Watertown, MA) sampled at a rate of 50Hz. Center of pressure area and average velocity

were calculated with Balance Clinic software (AMTI, Watertown, MA). Time to boundary (TTB) mean minima and standard deviation (SD) were processed using customized software in MatLab (MathWorks, Inc. Natick, MA). Prior to each administration the forceplate was calibrated using an internal calibration file specific to the forceplate. Participants stood in a self-selected comfortable bilateral stance on the forceplate. The participant's feet were then centered medially and laterally, and anteriorly and posteriorly, as the child would allow with an attempt to keep the feet parallel. Foot placement was documented using the pre-determined grid on the surface of the forceplate, which allowed investigators to keep placement constant throughout the study. Three 10 s trials were administered with EO, and then three 10 s trials were administered with the eyes closed (EC). The participants were asked to close their eyes for EC trials a blindfold was not used. The averages for EO and EC for COP area and velocity were calculated with Balance Clinic software for each trial and an average of the three trials were used for analysis.

### ***Timed up and go.***

A location was identified inside the participant's home that was level and straight, and was used throughout the study to administer the Timed up and Go (TUG) and GV. The flooring type (carpet, tile, hardwood) was recorded. The TUG was administered barefoot for all participants, and at each session the identified location was re-measured prior to administration.

Participants were seated in a folding chair provided by the investigator with the feet flat on the ground. They were then instructed to stand up, walk as quickly and safely as possible to touch an object that was 3 meters away, and turn around and return to the seated position in the chair. The time to complete the task was recorded and three trials were administered. The fastest time was used for analysis.

### **Gait Velocity**

The location identified for use during the TUG was also utilized during GV. The participants were barefoot and instructed to walk at their usual pace over a pre-measured 3 m distance. The time to ambulate was recorded in seconds. GV was calculated by

dividing 3 m by completion time. Three trials were administered and the fastest velocity was used for analysis.

### **Isometric Strength Test: Hip Abductors**

Isometric strength of the hip abductors (HAS) was assessed with a Power Track II Commander hand-held dynamometer (JTech Medical, Salt Lake City, UT). The dynamometer was calibrated with a 5 lb weight one time per week before testing for all participants. All participants were asked to perform a “make” test in which the participant was asked to push as hard as possible for 5 seconds while resistance was slowly increased (Berry et al., 2004). Two trials were performed and the maximum score, in pounds, was recorded for each trial. If the two trials were not within 10% of each other, trials continued until there were two consecutive trials within 10% of each other (Lowes et al., 2004). Most participants required an average of three trials and the maximum was five. The maximum score of the two trials was used for analysis. On the first day of baseline testing, both limbs were assessed and the weaker limb was chosen for all further assessments.

Each participant was instructed to lie supine on the floor with the hip and knee extended. The hip was positioned in the neutral position with 0° abduction, 0° adduction, and 0° rotation (Berry et al., 2004). Support was provided at the contralateral pelvis with the examiner’s hand to prevent the participant from moving during testing. (Figure 3.2) The dynamometer was positioned 5 cm proximal to the lateral femoral epicondyle (Berry et al., 2004), which was measured with a tape measure and marked on the skin with a felt-tip pen. The participant was instructed to push as hard as they could, and during administration the examiner provided verbal feedback.

### **Activities Scale for Kids, performance version**

The ASKp (Appendix B) was left with the participants to complete with assistance of their parents if necessary once per week during the entire study. The participants and family documented how much help was required to complete the ASKp. The total score used for analysis was calculated with the provided software from the authors (Young et al., 2000).

## **Enjoyment and Difficulty Questionnaire**

The enjoyment and difficulty of the intervention was assessed with the use of a three-item questionnaire (EDQ, Appendix C). The first two questions were modified from an adult study investigating the enjoyment, engagement, and difficulty of balance training (Brumels et al., 2008). There is no reported reliability or validity of the adult questionnaire. A third question was added to address what the participant specifically liked and disliked about the games. During the last administration of the EDQ participants were also asked what they would change about the study. Questions were read to the participants and the participants circled or pointed to their response.

## **Procedures**

The following section describes the procedures for study, beginning with reliability procedures, followed by the testing and intervention procedures. The phases of the study (baseline, intervention and maintenance) are then discussed.

### **Reliability**

#### ***Inter-rater reliability.***

Inter-rater reliability was tested throughout the study between the primary researcher and a licensed physical therapist. There was one physical therapist from New York and one from Kentucky. Three of the five participants were randomly assigned to be part of reliability testing, one in New York and two in Kentucky. During the study reliability testing of TUG and GV occurred during all three phases. Specifically, 1 test occurred at baseline, 2 during the intervention and 1 during maintenance for all three participants. Table 3.2 presents when the reliability testing occurred for the selected participants by session number.

During reliability testing of the TUG and GV the primary researcher gave all instructions to the participant and both the primary researcher and the physical therapist timed each trial. Three trials of each test were performed.

Inter-rater reliability of HAS was performed on two participants from KY. The primary researcher tested HAS first as described previously while the reliability therapist observed. The reliability therapist then repeated the administration of HAS, including re-marking of where the dynamometer was to be placed using a different colored felt-tip pen.

Reliability of HAS occurred once at baseline, twice during intervention and once during maintenance for participant 4, and once during intervention and once during maintenance for participant 5.

Inter-rater reliability of WBS, COP, TTB, ASKp and EDQ was not performed. The WBS, COP and TTB reliability were assessed through procedural reliability, discussed in the following section.

### ***Procedural reliability.***

Procedural reliability occurred for the measures of WBS, COP, HAS and for baseline, intervention and maintenance procedures. Phase procedures were addressed in two manners, first by establishing separate checklists (Appendices F-I) for each phase that was utilized during each session. Second, by having an outside observer verify that the checklist was being followed at three intervention sessions for each participant.

In addition, procedural reliability was also addressed by having the reliability physical therapist confirm: foot placement for COP testing, placement of the hand-held dynamometer, and foot placement for WBS. Procedural reliability for COP, WBS and HAS occurred at the same sessions as inter-rater reliability: once during baseline, twice during intervention and at maintenance. Foot placement during COP testing was confirmed by having the therapist refer to a graphic documenting where the borders of the feet were to be on the forceplate grid. During WBS testing the reliability therapist re-measured the distances between the medial malleoli and the medial borders of the first metatarsal heads to confirm that the distances matched what was established on the first day of testing. The therapist also recorded the score of the WBS. For HAS the primary researcher measured and marked where the dynamometer would be placed and the physical therapist re-assessed the distance to confirm that the placement was 5 cm proximal to the lateral femoral epicondyle. Upon confirmation the primary researcher continued with administration of HAS and both the researcher and therapist recorded the score.

### **Testing Procedures**

The participants selected the order of administration of the measures and wore a safety belt. During the baseline phase HAS, GV, TUG, COP, TTB and WBS were



administered one time per session (Figure 3.3). The ASKp was administered once during the baseline phase, while the EDQ was not administered. During intervention phase COP, TTB and WBS were administered at every session for a total of 18 times (Figure 3.4), while HAS, GV, and TUG were administered one time per week and on the final day of the intervention session, for a total of seven times. The ASKp and EDQ were administered once per week during the intervention phase, for a total of six. At maintenance phase all outcome measures, except the EDQ, were administered once.

### **Intervention Procedures**

#### ***Balance-training intervention.***

The therapist directed video-game based balance-training intervention was designed with games from the WiiFit™ Plus software utilizing the WBB. All games were played on the WBB in a comfortable, self-selected stance in barefeet or socks and a safety belt was worn. The only restriction was that the feet of the participant had to be kept on either side of the dividing line on the WBB; the participants were encouraged verbally to keep their feet within the imprinted rectangles for better game play.

Four balance games were preselected for the participants that focused on lateral and multi-directional weight shifting. The lateral games were soccer heading (SH) and penguin slide (PS, Figure 3.5), while balance bubble (BB) and table tilt (TT, Figure 3.6) were multi-directional. Complete descriptions of the games are presented in Appendix D.

#### ***Intensity and frequency of intervention.***

The participants received the video-game based balance-training intervention at home under the direct supervision of a licensed physical therapist. The intervention occurred 3 times per week for 30 minutes across 6 weeks. To ensure that equal time was played on games that focused on primarily lateral weight shifting (15 minutes) and multi-directional weight-shifting (15 minutes) the games were played a predetermined number of times. SH was played 8 times, BB 8 times, PS 4 times, and TT 6 times all at the beginner difficulty setting. As the participant progressed through the different difficulty settings, the maximum number of trials changed accordingly. Progression through the difficulty settings was determined by the therapist and participant request; at a minimum, participants had to successfully complete a game repeatedly over one week to the two star

rating (Appendix E) before they would be considered for progression to the next difficulty setting.

### **Description of Phases**

#### ***Baseline phase (Week 1).***

Participants were randomly assigned a pre-determined baseline length of 3, 4 or 5 sessions (Figure 3.3) conducted over 10 days time at the participants' homes (Shumway-Cook et al., 2003; Woollacott et al., 2005). The baseline lengths were predetermined because though balance is variable it has been found to be stable across days (Rose et al., 2002), and GV and strength are consistent in children with CP not undergoing intervention (Engsberg et al., 2006). Baseline lengths were also predetermined to minimize the time commitment of no intervention for the participants.

#### ***Intervention phase (Weeks 2-7).***

During intervention phase the TUG, GV, HAS and ASKp were administered at the start of each week in a participant-selected order. Each intervention session began with administration of the following tests, in a participant selected order, COP, TTB and WBS followed by the balance-training intervention (Figure 3.4).

Participants were encouraged to play as many games as possible without breaks. A break was defined as stoppage of the intervention lasting 2 minutes or greater. The number of breaks and requests to change activities were tracked. To minimize distractions only the physical therapist, participant and one parent, who was asked to remain quiet during the game, were in the room. The parent was allowed to leave the room. Participants were allowed to receive positive praise, verbal and physical (hugs, kisses, high-fives) from their parent during and following the intervention.

During the balance-training intervention the participants were provided with feedback that included their score and ranking as well as movement feedback from the therapist. Participants were encouraged during game with statements such as “move your bottom” and “keep your feet on the board” and “move your bottom and your shoulders.” Visual demonstration of the games or the movements was utilized as necessary at the therapist's discretion. Physical assistance was used during the first 2 weeks of the intervention period upon participant request. On the last day of the intervention all

participants were administered all measures (HAS, GV, TUG, COP, TTB, WBS, ASKp, and EDQ).

***Maintenance follow-up (Week 8).***

At 1 month post the last intervention session follow-up testing of all measures (HAS, GV, TUG, COP, TTB, WBS, ASKp) were administered in one session.

**Data Analysis**

**Visual analysis.**

All data was graphed and analyzed using Microsoft Excel 2011 for Macintosh. Data from each of the subjects and each of the measures were analyzed using visual analysis, except the ASKp and EDQ. Visual analysis began with the baseline phase for all measures, establishing the mean, level and trend, visually assessing the variability, and then computing the two SDs around the mean and continued with intervention phase data. Intervention data was then compared to baseline phase data using the two SD band method. A significant change in behavior was defined *a priori* as three consecutive data points in the intervention phase that were outside of the two SD band lines from the baseline phase (Kazdin, 1982; Portney & Watkins, 2008a). The WBS data was also analyzed by counting the number of data points that fell within the 48-52% band displayed on the graphs, and three consecutive points within the band was considered a significant change.

**Statistical analysis.**

Data analysis was also conducted statistically using Microsoft Excel 2011 for Macintosh. A significant difference between baseline and intervention phases was determined *a priori* as  $p < .05$ . The *C* statistic was used to statistically analyze the trends in the data between the baseline and intervention phases for all measures except the

$$C = 1 - \frac{\sum_{i=1}^{n-1} (x_i - x_{i+1})^2}{2 \sum_{i=1}^n (x_i - \bar{x})^2}$$

ASKp. The *C* statistic was calculated using the following formula

where  $x_i$  = was the *i*th data point in the *n* data points in phases A and B, and  $\bar{x}$  = overall

mean (Satake, Jagaroo, & Maxwell, 2008). The *C* statistic was then converted to a *Z* score by dividing by the standard error of the phase based upon the number of data points per phase. The *Z* score was then used to assess if there was a statistically significant trend in the data ( $Z > 1.645$  for  $p < .05$ ). Calculation of the *C* statistic began with baseline data and if no significant trend existed, then the baseline data was pooled with the intervention data and analyzed for a significant change in trend (Portney & Watkins, 2008a).

Data was analyzed for effect size for all measures that demonstrated significant changes through the SD band method or *C* statistic. The improvement rate difference (IRD) was selected because it allows for a baseline to intervention comparison and could be averaged across participants in a multiple-baseline design (Parker & Hagan-Burke, 2007; Parker, Vannest, & Brown, 2009). The IRD correlates with other traditional effect size measures including Pearson's *R* and Kruskal-Wallis square-root of *W*, but has fewer statistical assumptions than these traditional measures (Parker et al., 2009). An interpretation guideline for the IRD is,  $IRD \leq .50$  is small, between  $.50$  and  $.70$  is moderate and  $>.70$  is large (Parker et al., 2009).

The IRD was calculated by counting the number of data points in each phase and then ordering them by phase from smallest to largest. The next step was to determine the IRD for each phase. For the baseline phase the IRD (IRDA) was the number of data points that overlap with the intervention phase (overlapA) divided by the total number of

data points in the baseline phase (countA), or  $IRDA = \frac{overlapA}{countA}$ . The IRD for the intervention phase (IRDB) was the difference between the total number of data points in the intervention (countB) and the number of overlapped data points with the baseline phase (overlapB), all divided by the total number of data points in the intervention phase,

or  $IRDB = \frac{(countB - overlapB)}{countB}$ . To determine the overall IRD for the participant the

IRD was the difference between the intervention and baseline phases, or  $IRD = IRDB - IRDA$  (Parker et al., 2009). For this study the data was reduced by one decimal place for each measure to allow for more representative IRD.

### ***Reliability analysis.***

Reliability data was analyzed using the standard error of measure with 95% confidence intervals for each participant that participated in reliability testing. The standard error of measure (SEM) was calculated by:  $SEM = s_x \sqrt{1 - r_{xx}}$  where  $s_x$  is the SD of the scores from the participant and  $r_{xx}$  is the reliability coefficient (Portney & Watkins, 2008b). The reliability coefficient was calculated from a Pearson correlation coefficient from the individual participant's data.

## **Results**

### **Intervention Summary**

All of the participants successfully completed a therapist supervised, 6 week multi-directional video game based balance-training intervention. Three participants owned a Nintendo Wii and WiiFit at the beginning of the study. The intervention occurred three times per week at the participant's home and was scheduled for 30 minutes (average 28 minutes). Occasionally an intervention session ended early due to participant and family commitments (Table 3.3). Most participants were able to complete the entire 30 minute protocol without difficulty, though evidence of fatigue was shown in their posture during game play, sitting down between games and bargaining with researchers. Participant 5 was frequently under the required 30 minute goal, though met the minimum requirements for the number of times each game was to be played. Figure 3.7 presents the average session length for each region and overall.

During each intervention session the number of rest breaks lasting greater than 2 minutes and the number of requests made to change activities from the intervention were tracked. Some participants (1, 3, 5) had one or less rest breaks per week, while participant 2 required more. A trend towards a decreasing number of rest breaks per session was observed across all participants (Figure 3.8). The frequency of requests to change activities followed a similar pattern to that of the rest breaks; participants 3 and 5 never requested to change activities, and participant 1 only requested twice during the first week (Figure 3.9).

## Reliability Results

Inter-rater reliability data was collected on participants 3, 4 and 5. For participant 3 TUG and GV were assessed while participants 4 and 5 assessed TUG, GV, and HAS. Reliability data is presented in Tables 3.2 (schedule) and 3.4 (results).

## Balance

### Weight-bearing symmetry.

Results of WBS are presented in Figure 3.10 and Table 3.5. No significant trends were observed in the data for any of the participants ( $Z < 1.645$ ). All participants increased in their number of sessions within the 48-52% range between baseline and intervention, except participant 3. Participants 1 and 2 met the *a priori* criteria for a significant change and exhibited three consecutive points that fell within the band during intervention phase. Their average IRD was 0.61.

### Center of pressure area.

Equipment failure occurred for all participants, two occurred during baseline (participants 2 and 3) and one session was missed. Two participants missed one session during intervention (participant 1 and 5), while one participant missed two sessions during intervention (participant 4). Maintenance data was collected on participant 4, but unable to be used due to processing errors.

### Eyes open.

COP area results for EO are presented in Figure 3.11 and Table 3.6. All participants had non-significant trends during baseline phase. Participants 2 and 3 had significant decreasing COP area with EO during intervention phase ( $Z = 2.787, 3.415$  respectively). An IRD was calculated for participants 2 and 3 and the average IRD was 1.00.

### Eyes closed.

Results of COP area EC are presented in Figure 3.12 and Table 3.6. All EC testing for participant 1 varied from the established protocol, as he had an intense fear of falling while standing with his EC and was only able to perform one trial, until the maintenance phase, where two trials were able to be performed.

The baseline phase of all participants displayed no significant trends with minimal variability. Participants 2, 3, and 4 had significantly decreasing COP area with EC during the intervention phase ( $Z= 2.774, 2.667, 2.55$  respectively). Effects sizes were calculated for COP area with EC for participants 2, 3, and 4, with an average of 1.0 (Table 3.6).

#### **Center of pressure velocity.**

##### ***Eyes open.***

COP velocity with EO results are presented in Figure 3.13 and Table 3.7. No significant trends were observed in the baseline phase of any participant. During the intervention phase participants 2 and 5 had significantly decreasing COP velocity with EO ( $Z= 3.22, 1.98$  respectively), and participant 5 also displayed a shift in level. Their average IRD was 1.00.

##### ***Eyes closed.***

COP velocity results with EC are presented in Figure 3.14 and Table 3.7. Participants 1, 2, and 3 had stable baseline phases, while participant 4 displayed a decrease that was not significant and participant 5 had a counter-therapeutic increase that was not significant. The intervention phase of participant 3 had significant decreasing trends ( $Z= 1.83$ ), while participant 5 had a counter-therapeutic increasing trend ( $Z= 2.92$ ). Participant 2 displayed a significant change in level during intervention, with 10 of 18 sessions below the lower SD band. Effect sizes were calculated for participants 2, 3, and 5, and their average IRD was 0.80.

#### **Time to boundary mean minima, anterior-posterior.**

##### ***Eyes open.***

Figure 3.15 and Table 3.8 display the results of TTB mean minima with EO for the anterior-posterior (AP) direction. During the baseline phase each participant displayed a different non-significant pattern for TTB mean minima AP EO. Participant 2 had an increase during intervention phase ( $Z= 3.21$ ), with an IRD of 1.00. No other significant trends were observed for the other participants.

### ***Eyes closed.***

Time to boundary mean minima with EC for the AP direction results are presented in Figure 3.16 and Table 3.8. Participants 2 and 3 had stable baseline phases, while participants 1 and 4 displayed a non-significant increase and participant 5 had a non-significant decrease. During the intervention phase participants 1 and 2 both had at least 3 consecutive sessions above their upper SD band, while participant 5 had a counter-therapeutic trend ( $Z= 2.30$ ). IRDs were calculated for participants 1, 2 and 5. Therapeutic changes were observed with participants 1 and 2 and their average IRD was 1.00, while a counter therapeutic change was found in participant 5 (0.69).

### **Time to boundary mean minima, medial-lateral.**

#### ***Eyes open.***

TTB mean minima with EO for the medial-lateral (ML) direction results are presented in Figure 3.17 and Table 3.8. Stable baseline phases were observed in participants 2, 4 and 5, while participant 1 displayed an inverted U shape, and participant 3 had a small decrease. An increasing trend ( $Z= 2.46$ ) was observed for participant 2 during intervention phase, while all others were not significant. Participant 4 had three consecutive sessions above her upper SD band. Effect sizes were calculated for participants 2 and 4, with an average IRD of 0.80

#### ***Eyes closed.***

TTB mean minima with EC for the ML direction results are presented in Figure 3.18 and Table 3.8. No significant trends were identified during baseline phase for all the participants, except participant 5 who displayed a counter-therapeutic trend ( $Z= 1.756$ ). Therapeutic trends were found in participants 1 and 2 during intervention ( $Z= 3.070$  and  $3.146$ ), and the counter-therapeutic trend continued for participant 5. No significant changes were observed for participants 3 and 4. IRDs were calculated for participants 1, 2, and 5. Therapeutic effects were an average of 1.00 (participants 1 and 2), while a counter-therapeutic effect was found for participant 5 (0.38).



### **Time to boundary standard deviation, anterior-posterior.**

#### ***Eyes open.***

Figure 3.19 and Table 3.9 present the data for TTB SD in the AP direction with EO. The baseline phase trends varied between participants, with only participant 3 having a significant, therapeutic, increasing baseline ( $Z= 1.89$ ). During the intervention phase only participant 2 had a significant increase ( $Z= 1.96$ ), though the mean did not differ from baseline. The IRD for participant 2 was small (0.22).

#### ***Eyes Closed.***

Figure 3.20 and Table 3.9 present the TTB SD for the AP direction with EC. No significant trends were observed during the baseline phase for participants 1, 2, and 4. Participant 3 had a therapeutic trend ( $Z= 1.80$ ) during baseline phase, while participant 5's was counter-therapeutic ( $Z= 1.71$ ). During the intervention phase no significant trends were observed in participants 1, 3, and 4. Participant 2 had four consecutive sessions about her upper SD band, while participant 5 continued her counter-therapeutic trend established during baseline. IRDs were calculated for participants 2 and 5. A therapeutic IRD was found for participant 2 (1.00), while participant 5's was counter-therapeutic (0.69).

### **Time to boundary standard deviation, medial-lateral.**

#### ***Eyes open.***

Figure 3.21 and Table 3.9 present the TTB SD data for the ML direction with EO. There were no significant trends identified in any participant during baseline phase or intervention phase. Participants 2 and 4 did have at least three consecutive sessions above their upper SD bands. Effect sizes were calculated for participants 2 and 4, and their average IRD was 1.00.

#### ***Eyes Closed.***

Figure 3.22 and Table 3.9 present the results of TTB SD in the ML direction with EC. All participants had non-significant trends during baseline phase. Participant 1 had a therapeutic increasing trend during intervention phase ( $Z= 1.95$ ), while participant 5 had a counter-therapeutic trend ( $Z= 2.48$ ). No other significant trends were identified in

participants 2, 3, and 4 during intervention. A therapeutic effect size was found for participant 1 (1.00), while a counter-therapeutic effect was found for participant 5 (0.69).

### **Timed up and go.**

All participants completed the TUG in their barefeet, and four participants were tested on hardwood floors and one on carpet. Results from the TUG are presented in Figure 3.23 and Table 3.10. The baseline phase trend for the TUG varied among participants, with only participant 2 displaying a significant counter-therapeutic trend ( $Z=1.85$ ). The intervention phase demonstrated no changes for participants 1, 3 and 5. Participant 2 reversed his counter-therapeutic trend from baseline and had a significantly increasing trend during intervention ( $Z=2.11$ ). Participant 5 had an immediate shift in level for the first three intervention sessions, and then she returned to baseline levels. Effect sizes were calculated for participants 2 and 4. A large therapeutic effect was found for participant 2 (1.00), and a counter-therapeutic effect was found for participant 4 (0.52).

### **Gait Velocity**

Results of GV are presented in Figure 3.24 and Table 3.11. No significant trends were identified in the baseline data of any participant. Increases in GV during intervention were found for participant 2 and 3 ( $Z=2.46$  and  $2.05$ ), while participant 4 demonstrated a decreasing GV during intervention with a significant number of sessions below her lower SD band. Participant 1 and 5 had no significant changes in GV during intervention. IRD effects sizes were calculated for participants 2, 3 and 4. Their average IRD was 0.39.

### **Strength of the Hip Abductors**

HAS results are presented in Figure 3.25 and Table 3.12. Participants 1, 2 and 5 were weaker on the right side, while participants 3 and 4 were weaker on the left. Participants 4 and 5 had significantly increasing baseline trends ( $Z=2.25$  and  $1.66$ ), while all other participants had no significant trends. Increases in HAS were found in participants 2 and 3 during intervention ( $Z=2.04$  and  $2.53$ ), with both participants also demonstrating at least three consecutive sessions above their upper SD band. No significant trends were identified in participants 1, 4 and 5 during intervention for HAS,

though participant 4 had a shift in level. IRDs were calculated for participants 2 and 3, with an average IRD of 0.21.

### **Activities**

Results from the ASKp are displayed in Figure 3.26 and Table 3.13. Because the ASKp was only administered once during baseline phase SD bands were inappropriate.

Results from the ASKp for participant 1 are minimal for the intervention phase, as there were only two returned. These two data points in the intervention phase were significantly larger than the baseline phase and had a mean value greater than baseline. This increase was maintained at the 1 month follow-up.

Intervention results for the ASKp for participant 2 had a higher return rate than participant 1; he returned 5 of 6. There was a slow increase in ASKp scores over intervention, and his mean was larger than baseline. This increased score was continued at the maintenance follow-up.

The ASKp return rate for participant 3 was poor with only 3 of 6 being returned from the intervention phase. A small increasing trend was observed during the intervention phase and the intervention mean was larger than baseline.

Participant 4 had a good return rate during the intervention phase, returning 5 of 6 ASKp. She was the only participant to complete the ASKp without adult assistance. During the intervention phase her scores decreased slightly from baseline, but returned to baseline levels by the maintenance follow-up.

The return rate of the ASKp for participant 5 during the intervention phase was 5 of the possible 6. Scores of the ASKp for participant 5 were stable during the intervention phase, with an increased mean compared to the baseline score.

C statistics were unable to be computed due to the number of baseline phase data points, thus data was evaluated on the minimum important clinical difference, a SD of 1.73 or greater (Young et al., 2000). Participants 2, 3, and 5 had SDs greater than 1.73 and IRDs were calculated based on this change. The average IRD was 1.00.

## Games

### Enjoyment and difficulty questionnaire.

The EDQ was only administered during the intervention phase. Individual results for each intervention week are presented in Figure 3.27, while average results are in Figure 3.28. Four participants dictated their responses, while one participant wrote in the responses to the open-ended question. Individually, the participants varied in their week-to-week responses, but the average results indicate that the first four weeks of the study were more challenging and showed a slight decrease in the difficulty of the intervention. Week 5 marked the turning point as participants reported that intervention was difficult. The enjoyment of the intervention varied minimally throughout the study.

Participant 1 found the intervention more difficult and less enjoyable the first 3 weeks, and for the last 3 weeks he rated that intervention easier and more enjoyable. Participant 2 found the intervention more difficult weeks 2 and 4, and less difficult on other weeks, with missing data for week 6. He found the games enjoyable throughout the intervention. Participant 3 reported the intervention was difficult, became easier week 3 through 6 and was difficult again at week 7. The enjoyment of the intervention had an increasing and decreasing pattern for participant 3. Participant 4 rated the intervention difficult (4) for all the weeks of the study, but enjoyable (1) as well. Participant 5 reported that the games were not difficult and were enjoyable for 5 of the 6 weeks, with the final week becoming more difficult.

### Mastery.

All participants began the games at the beginner setting. Two of the participants (1, 2) were able to progress through all the difficulty settings for each game. Participants 3 and 4 progressed through all difficulty settings for the BB and SH games, but did not progress to the final difficulty setting of TT. Participant 5 remained at the beginner settings for all the games. Results from SH, BB, PS, and TT are presented in Figures 3.29 through 3.32. Participants 1, 2, 3, and 4 increased their scores for all the games across the intervention phase. Participant 5 made minimal increases in score for most games.

## Discussion

### Balance

The clinical measure for balance, the TUG, demonstrated minimal changes across participants. While decreasing trends were observed in 2 of 5 participants, none made significant changes from their baseline scores. Participant 4 even increased her time to complete the TUG during the intervention phase. One explanation for the lack of significant change in TUG scores is that the scores of these participants were more similar to TD children. TUG scores previously reported in the literature for TD children ranged between 4.9 and 7.0 seconds (Katz-Leurer, Rotem, Lewitus, Keren, & Meyer, 2008; Williams et al., 2005). Participants in this study ranged at baseline between 5.40 and 6.40 seconds, demonstrating a possible ceiling effect of the tool. Previously reported TUG scores for children with disabilities have been reported to be between 8.0 and 10.1 seconds prior to intervention (Crompton et al., 2007; Katz-Leurer et al., 2009; Katz-Leurer et al., 2008). Clearly the participants were significantly faster at performing the TUG than other children with disabilities.

The forceplate measure of COP area and velocity with EO and EC had more powerful results than the clinical TUG. While it was anticipated that participants would decrease their COP area with EO and EC, this was not supported across all participants. Significant decreases in COP area with EO and EC were observed in two participants (2, 3) with both demonstrating data points consistently staying below their bottom SD band and *C* statistics indicating significant decreasing trends. Participant 4 also had a decreased COP area with EC. Decreases in area following intervention have been previously reported in the literature for children with CP (Ledebt et al., 2005; Shumway-Cook et al., 2003). Changes in COP area may be attributed to the small surface area of the WBB on which participants were required to weight shift to control the games.

The other three participants displayed varying results for COP area. Participant 5 approached a decreasing trend during intervention phase, though visually demonstrated decreases in her COP area with her EO, and not EC. A lack of visual input for participant 5 caused significant increases in her COP area that did not improve with intervention. As she progressed through the intervention participant 5's COP area with EC varied greatly, more than in baseline, which suggests that she may have been in a learning phase rather

than a refinement phase (Adolph, 2008; Adolph et al., 2011; Kamm, Thelen, & Jensen, 1990). Participant 1 had such minimal COP area that he resembled a TD child, rather than a child with CP. Due to the small area established at baseline there was no way for him to make a significant change based on the two SD band. Participant 4 had similar results to participant 1 in that her baseline COP area was small and thus her ability to make a significant change based on the two SD band method was limited. She did trend towards a decrease visually with EO and had a significant decreasing trend with EC between the baseline and intervention phases for COP area. Participant 4 had a greater opportunity to make changes in the EC condition because she started at a larger COP area.

It was hypothesized that COP velocity would decrease during intervention. In contrast to COP area results COP velocity demonstrated changes in only two participants regardless of condition. Participants 2 and 5 had significant decreases in COP velocity with EO and participant 5 had a decrease in variability with EO. Participants 2 and 3 decreased their COP velocity with EC. Both participants 1 and 4 had no significant changes to COP velocity. The COP velocity with EC for participant had a counter-therapeutic change during intervention, suggesting that the video-game based balance training intervention increased her reliance on vision since her velocity increased with EC and decreased with EO.

Changes in COP area and velocity suggest that changes were beginning to occur in the sensory-motor systems responsible for the maintenance of balance. Two participants decreased their COP area with EO and three decreased with EC, while for COP velocity two participants decreased for both EO and EC. The changes were small, though statistically significant and may be another explanation for why no changes were observed in the TUG.

TTB results further supported that changes were occurring in sensory-motor systems of participants. Four of five participants had change in in at least one measure of TTB mean minima. Participant 2 had significant increases in his mean minima, or overall time to make a correction, in both AP and ML directions with EO and EC. He was the only participant to demonstrate changes in every direction and condition for TTB. In the EC condition for TTB mean minima participant 1 demonstrated significant increases for both AP and ML directions, which has been reported in other balance training literature

(McKeon et al., 2008). Participant 1 reported a heightened fear of falling at the beginning of the study and refused more than one trial with EC, though by the maintenance follow up he was able to tolerate two trials. Based on his TTB results with increased mean minimas with EC (AP and ML) and increased SD with EC (ML), the balance training intervention may have increased his confidence and possibly decreased his fear of falling with EC.

Anterior-posterior COP sway changes have been previously reported in the literature for children with CP following balance training interventions (Ledebt et al., 2005). The gradual increases in TTB mean minima for AP and ML directions displayed in the three participants with spastic diplegia have been similarly reported in other studies examining COP area in children with spastic diplegia (Shumway-Cook et al., 2003). The other subject to demonstrate a significant change in TTB mean minima was participant 4 in the ML direction with EO. Change in the ML direction using COP data in quiet stance has not previously been found in the literature for children with CP (Ledebt et al., 2005), but has been reported for adults with chronic ankle instability following intervention (Hoch & McKeon, 2011). It has been reported in the balance and gait literature that ML control for children with CP is impaired, thus results from this study suggest that a multi-directional balance training intervention may improve ML control (Hsue et al., 2009a, 2009b; Liao et al., 1997; Wheelwright, Minns, Elton, et al., 1993).

TTB SD results revealed fewer changes than mean minima. Significant increases in variability of the time to make a correction occurred for participants 1, 2, and 4. Most changes were observed in TTB SD ML with EO and EC with two participants for each. Similar results with EC were reported by McKeon and colleagues (2008), and improvements with EO have been reported following joint manipulation (Hoch & McKeon, 2011). These results suggest that while the overall time increased for three participants, this did not translate to increased variability, or increased solutions, with the multi-directional balance training intervention.

Participant 5 had three instances of counter-therapeutic trends with TTB data: mean minima ML and SD AP and ML all with EC. All occurrences of negative trends occurred with EC, which also happened with her COP velocity EC. She appeared to be highly dependent on vision at the start of intervention and the visual demands of the

video games may have further increased her visual dependence. Her therapeutic changes of COP velocity with EO, suggest that the intervention phase was a period of motor learning and the counter-therapeutic changes with EC in velocity and TTB data were from the natural increases in variability that occur in the first portion of the motor learning paradigm (Adolph, 2008; Adolph et al., 2011; Kamm et al., 1990). At maintenance for the majority of the measure with counter-therapeutic trends she had returned to baseline levels, suggesting that she refined her behaviors during that 1 month period without intervention.

Examining the TTB mean minima data and SD data based on direction, it appears that the greatest change occurred in the ML direction. Three participants increased the time and variability components. With the known decreased postural control and gait impairments in the ML direction for children with CP, this data suggests that TTB is a sensitive measure to detect changes in postural control in the ML direction during and following multi-directional balance training. Both Hoch and McKeon (2011) and McKeon and colleagues (2008) found significant improvements in ML direction following intervention.

The WBS data demonstrated no significant trends. None of the participants were able to consistently stabilize within the 48-52% range that Nintendo suggests is appropriate. Participants 1 and 2 were briefly able to stabilize in the range, but it was not maintained. This may be due more to the sensitivity of the WBB than the actual participants. In other studies it has been reported that the WBB is reliable (Clark et al., 2010; Schlueter et al., 2010), but it is referring to the WBB and not the WiiFit software output. With the number of TTB results with improvements in the ML direction one would expect that more changes would have occurred in the WBS data. Thus the WBS output from the WiiFit software does not appear to be a sensitive outcome measure to monitor change over time in ML control when compared to more established measures such as found with a piezoelectric force plate.

Combining the clinical and laboratory measure of balance suggest that the balance training intervention demonstrated some improvements on the balance of children with CP, specifically in the ML direction. The laboratory measures were more sensitive to changes occurring than the clinical measures in these high functioning children with CP.



## Gait Velocity

It was hypothesized that GV would increase during the intervention phase for the participants. Similar to other outcome measures, this hypothesis was supported by two participants (2, 3). Participant 2 had significant increases in GV with consecutive points above his SD band and a significant *C* statistic. Participant 3's increases in GV were demonstrated with a positive trending *C* statistic and visually his GV remained at the upper two SD band for most of the intervention phase. The other participants had varying results. Participant 1 visually displayed an increasing trend, while participant 4 decreased her GV in the intervention phase, coinciding with her increased TUG time. Her decreased GV during intervention phase may be attributed to nervousness during testing that was not exhibited during the baseline or maintenance phases. Her guardian reported frequently after testing that she ambulated slower than usual. Participant 5 visually appeared to increase her GV, though it did not reach any statistical significance. The overall lack of change in GV across the participants may be attributed to their already fast GV. The GV of these participants were similar to reported values for TD. Velocities for TD children have been reported between 1.23 and 1.37 m/s (Dusing & Thorpe, 2007; Katz-Leurer et al., 2008). Reported GV for children with CP prior to intervention (0.40-1.10m/s) cross the TD range, so the values found among our participants were already close to typical (Eagleton et al., 2004; Katz-Leurer et al., 2009).

According to Sutherland's (1980) early work GV is a determinant of mature gait and increases most rapidly during the first 3 years, thus there is less opportunity for improvement in GV when a child has reached a mature gait pattern. All the participants were between 5 and 10 years of age and were assumed to have a mature gait pattern, thus based on Sutherland's (1980) work there would be less ability to increase GV. A formal gait analysis was not performed, so there is no way to confirm that their gait was mature. The gait kinematics and kinetics of children with CP are different from TD children (Hicks, Schwartz, Arnold, & Delp, 2008; Hsue et al., 2009a, 2009b; Iosa, Marro, Paolucci, & Morelli, 2012; Romkes et al., 2007; Wheelwright, Minns, Elton, et al., 1993; Wheelwright, Minns, Law, et al., 1993), thus Sutherland's (1980) determinants of mature gait while applicable, may have greater flexibility in the time frame in children with CP.

GV also may not have increased due to a lack of specificity of training. Most intervention studies that demonstrate increased GV following rehabilitation for children with CP have focused specifically on gait training. In studies where the intervention focused on other aspects, such as strength training, GV has not significantly improved across the subjects (Damiano et al., 2010). The current research supports that the most efficient and effective way to increase GV in children with CP treadmill training (Mattern-Baxter, 2009; Willoughby, Dodd, & Shields, 2009; Zwicker & Mayson, 2010). Though GV and balance abilities have been correlated (Liao & Hwang, 2003), this study suggests that balance training alone may not be sufficient to make significant increases in GV, especially when the participants are already ambulating at a speed similar to their TD peers.

### **Hip Abductor Strength**

HAS was hypothesized to remain constant throughout the study. Three participants had no significant changes in strength across the baseline and intervention phases support this hypothesis. Two participants (2, 3) increased HAS during the intervention phase, and one maintained increased strength at one month follow up. It had been anticipated that HAS would not improve because this balance training intervention did not include any specific strengthening activities. For the two participants in which the HAS did increase it is theorized that these increases may have occurred due to increased use of the hip abductor musculature during the intervention. The muscle group most commonly cited as weak among the gait, balance and strength literature for children with CP was the hip abductors (Eek & Beckung, 2008; Lowes et al., 2004; Metaxiotis et al., 2000; Ross & Engsborg, 2007). Increased use may facilitate strengthening, as observed in two participants. Current guidelines for strengthening children with CP suggest that a strength training intervention last 6 to 10 weeks, occur 2 to 3 times per week and be at the intensity of 65% of the maximum isometric strength or 3 to 10 repetitions (O'Neil, Fragala Pinkham, et al., 2006). This study met the weekly frequency (3 times per week) and the minimum intervention length (6 weeks) of a strength training intervention, hence significant strength gains were not expected.

### **Activities Scale for Kids, performance**

The activities and participation of children with CP were not expected to change over the course of this study. Surprisingly, 4 of 5 participants demonstrated increases in activities measured by the ASKp. Three of the four represent true change in activities during and following intervention. Participant 1 did increase his score, but reported a falsely low score at baseline. The low score was due to the questionnaire not being completed in its entirety, but sufficient to garner a score, thus his score may not reflect all activities performed over that week. Young (2000) suggests that a SD score of greater than 1.73 per participant is indicative of clinical change in activities. Three of the participants had SDs greater than 1.73. While single subject design research of this nature cannot assume causation, it can limitedly infer that the intervention may have increased activities of the participants.

It is interesting that all of the children, except participant 4 had assistance in completing the ASKp and she is the only participant that demonstrated slight decreases during the intervention phase compared to baseline. The participation literature does suggest that parents of children with disabilities rate their child's ability differently than the child (Young et al., 1995). The other parents assisting their children complete the ASKp may have unintentionally biased their children to rate themselves higher because they were participating in this study.

### **Summary**

This pilot study suggests that a multi-directional video-game based balance training intervention may improve postural control through laboratory measures, which are not reflected in the selected clinical measure. The increases in control were demonstrated primarily in the ML direction, where children with CP have been reported to have the greatest variability and impairment. Therapist directed, video game based balance training may increase GV and HAS. A surprising finding was that of increased participation and activities for children with CP. To our knowledge this is the first study to investigate activities and participation during and following a video game based multi-directional balance training intervention. Results from this pilot work suggest that there is carryover from balance training into the everyday lives of the children with CP.

## **Limitations**

This study was a single subject design study and is limited that it cannot assume causation, but can only causally infer findings due to the level of the study (Romeiser Logan, Hickman, Harris, & Heriza, 2008). Were it a concurrent multiple baseline design there would be stronger inferences. The predetermined baseline length was problematic and is a limitation. Another major limitation of the study is in the reliability findings. Because reliability data was not collected on the NY subject there can be cause for concern when interpreting the increases in strength. Another limitation was that reliability data was not collected prior to undertaking the study.

The video games chosen for the study may not have been sufficiently intense to result in large changes to the sensory and motor systems of these children with CP. The weight shifts required to play the games may not have been large enough to bring them to the outer boundaries of their base of support, thus their opportunities to improve control may have been limited to within their comfortable base of support.

Participants came from two distinct regions of the United States and had very different intensities of therapy services (Table 3.1). While it did not appear to interfere with the results from this study, it is another possible source for error and variability.

## **Recommendations for Future Research**

For future research this study could be replicated with some suggested changes, including removing the TUG and replacing it with another clinical measure of balance, such as single limb stance time (Atwater et al., 1990) or the standardized walking obstacle course (Held et al., 2006). Single limb stance would be important because it is known that children with CP spend an increased time in double limb support during gait, thus a proportionally shorter time in single limb stance (Hsue et al., 2009a, 2009b; Wheelwright, Minns, Elton, et al., 1993). The WBS measure could continue to be investigated, though it is the authors' belief that while the transducers in the WBB may be sensitive the WiiFit software is not sensitive enough to monitor change. Thus, if interested in monitoring WBS another method, such as dual forceplates should be utilized (Dault, de Haart, Geurts, Arts, & Nienhuis, 2003; de Haart, Geurts, Dault, Nienhuis, & Duysens, 2005). Reliability, both procedural and inter-rater, should continue to be

collected across all the phases, but should be collected dually for all outcome measures, except the forceplate and WBS.

Other suggested changes include increasing the number of games. The WiiFit has other balance games that involve weight shifting, but were not selected for this study. The incorporation of these other games, especially games such as snowboarding where the body is turned away from the television may produce a larger sensory overload to challenge the balance of participants. While there were not significant improvements in all outcome measures for all the participants, there were enough improvements across them to suggest expanding this intervention to children with other developmental disabilities with known balance impairments, such as Down syndrome and autism spectrum disorder.

### **Conclusion**

This study sought to explore the effect of a therapist directed, video game based balance-training intervention on children with CP. No significant increases were observed in the clinical measure of balance, though improvements were observed with some laboratory outcome measures of balance. Small changes in GV and HAS were found in two participants each, with minimal changes in other participants. Significant changes were unexpectedly observed in activities and participation for three participants. While some improvements were displayed many of the participants demonstrated minimal changes. Further study is needed to determine the clinical application of video-game based balance training in children with disabilities.

Table 3.1

*Participant Demographics*

Participant	Age (years, months)	Gender	Diagnosis	GMFCS Level	Location	Therapies Receiving
1	7, 0	Male	Spastic diplegia	I	Rochester, NY	<u>Summer:</u> 45 minutes 1X/week aquatic PT <u>School-based:</u> 30 minutes 2X/week PT; 45 minutes 1X/week aquatic PT; SLP consultation
2	7, 9	Male	Spastic diplegia	II	Rochester, NY	<u>Summer:</u> 30 minutes 1X/week for PT and 60 minutes 1X/week aquatic PT <u>School-based:</u> 30 minutes 2X/week for PT; 60 minutes 1X/week aquatic PT; OT consult <u>Private:</u> 30 minutes 1X/week for PT
3	8, 1	Male	Spastic left hemiplegia	I	Rochester, NY	<u>Summer:</u> 45 minutes 2X/week for PT and OT <u>School-based:</u> 30 minutes 2X/week for PT; 30 minutes 3X/week for OT <u>Private:</u> 60 minutes 1X/week
4	9, 11	Female	Spastic left hemiplegia	I	Lexington, KY	<u>School-based:</u> 30 minutes 1X/week for OT <u>Private:</u> none
5	10, 4	Female	Spastic diplegia	II	Lexington, KY	<u>School-based:</u> 30 minutes 1X/week for OT; PT observation <u>Private:</u> 60 minutes 1X/month for PT; 60 minutes 2X/month for OT

*Note.* GMFCS= Gross motor function classification system; PT= physical therapy; OT= occupational therapy; SLP= speech language pathology

Table 3.2

*Schedule of Inter-Rater and Procedural Reliability Testing by Session Number*

Participant	Baseline	Intervention	Maintenance	
3	1	15	23	24
4	2*	13*	21*	22*
5	4	11	22*	23*

\* inter-rater reliability testing of HAS in addition to Timed Up and Go and gait velocity

Table 3.3

*Intervention Time Summary*

Participant	Location	Range (min)	<i>M</i> (min)	<i>SD</i>
1	Rochester, NY	22-39	30.9	4.1
2	Rochester, NY	20-34	27.7	3.5
3	Rochester, NY	28-32	29.9	1.4
4	Lexington, KY	22-31	26.6	2.8
5	Lexington, KY	22-25	22.9	1.0
<u>Overall</u>	Rochester, NY	20-39	29.5	3.5
	Lexington, KY	22-31	24.7	2.8
Total		20-39	27.6	4.0



Table 3.4

*Inter-rater Reliability Coefficients for TUG, GV, HAS*

Participant	TUG		GV		HAS	
	r	SEM	r	SEM	r	SEM
3	0.948	0.307	0.688	0.046		
4	0.949	0.184	0.837	0.046	0.315*	2.394
5	0.988	0.124	0.838	0.041	0.806**	2.434

*Note.* TUG = timed up and go; GV = gait velocity; HAS = hip abductor strength;  
r= Pearson correlation coefficient; SEM= standard error of measure

\*p< .05

\*\*p= .10

Table 3.5

*Weight Bearing Symmetry Results*

Participant	Phase	Side	<i>M</i> (%)	<i>SD</i>	<i>C</i> ( <i>Z</i> )	Number of points within the 48-52% range	IRD
1	Baseline	Right	46.6	10.3	0.48 (1.37)	1	0.22
	Intervention	Right	50.6	5.4	-0.30 (-1.44)	8	
	Maintenance	Right	54.6		-0.27 (-1.34)	0	
2	Baseline	Right	44.6	2.5	-0.11 (-0.30)	0	1.00
	Intervention	Right	51.0	8.7	0.28 (1.39)	6	
	Maintenance	Right	56.0		0.27 (1.35)	0	
3	Baseline	Left	46.1	6.6	-0.06 (-0.16)	2	
	Intervention	Left	42.3	5.5	0.25 (1.25)	1	
	Maintenance	Left	45.7		0.11 (0.58)	0	
4	Baseline	Left	43.6	8.4	0.12 (0.35)	0	
	Intervention	Left	47.5	4.2	0.32 (1.56)	4	
	Maintenance	Left	50.9			1	
5	Baseline	Right	32.4	12.1	0.02 (0.05)	0	
	Intervention	Right	33.1	7.0	0.02 (0.11)	1	
	Maintenance	Right	33.7		0.02 (0.14)	0	

*Note.* *C* = *C* statistic; *Z* = *Z* score; IRD = improvement rate difference

Table 3.6

*Center of Pressure Area Results*

Participant	Phase	Condition	<i>M</i> (cm <sup>2</sup> )	<i>SD</i>	<i>C</i> ( <i>Z</i> )	IRD
1	Baseline	EO	1.402	0.876	0.28 (0.80)	
		EC	1.525	1.089	0.08 (0.02)	
	Intervention	EO	1.172	0.663	0.07 (0.33)	
		EC	0.702	0.546	0.09 (0.44)	
	Maintenance	EO	0.438			
		EC	0.644			
2	Baseline	EO	8.013	1.387	0.49 (1.38)	
		EC	8.954	0.901	0.48 (1.36)	
	Intervention	EO	5.341	2.742	0.59 (2.85)*	1.00
		EC	7.084	3.221	0.72 (3.45)*	1.00
	Maintenance	EO	4.161			
		EC	2.878			
3	Baseline	EO	6.440	1.723	0.02 (0.05)	
		EC	7.921	1.175	0.63 (1.72)	
	Intervention	EO	4.813	2.134	0.74 (3.62)*	1.00
		EC	5.834	2.654		
	Maintenance	EO	8.787			
		EC	8.330			
4	Baseline	EO	3.678	1.261	0.476 (1.35)	
		EC	4.969	1.439	0.49 (1.38)	
	Intervention	EO	4.313	4.498	0.32 (1.45)	
		EC	4.039	3.142	0.55 (2.55)*	1.00

Table 3.6 continued

Participant	Phase	Condition	<i>M</i> (cm <sup>2</sup> )	<i>SD</i>	<i>C</i> ( <i>Z</i> )	IRD
5	Baseline	EO	24.823	5.229	0.56 (1.53)	
		EC	16.083	3.493	0.17 (0.45)	
	Intervention	EO	19.365	5.555	0.14 (0.68)	
		EC	18.691	6.530	0.29 (1.37)	
	Maintenance	EO	17.743			
		EC	21.572			

*Note.* *C* = *C* statistic; *Z* = *Z* score; IRD = improvement rate difference;

EO = eyes open; EC = eyes closed

\**p* < .05

Table 3.7

*Center of Pressure Velocity Results*

Participant	Phase	Condition	<i>M</i> (cm/s)	<i>SD</i>	<i>C</i> ( <i>Z</i> )	IRD
1	Baseline	EO	2.280	0.131	0.47 (1.33)	
		EC	2.448	0.315	0.07 (0.21)	
	Intervention	EO	2.280	0.155	0.01 (0.04)	
		EC	2.111	0.132	0.04 (0.20)	
	Maintenance	EO	2.057			
		EC	2.058			
2	Baseline	EO	2.761	0.119	0.50 (1.41)	
		EC	3.096	0.255	0.06 (0.16)	
	Intervention	EO	2.357	0.370	0.67 (3.22)*	1.00
		EC	2.589	0.341	0.37 (1.77)*	1.00
	Maintenance	EO	2.400			
		EC	2.208			
3	Baseline	EO	3.145	0.432	0.39 (1.07)	
		EC	3.473	0.208	0.57 (1.57)	
	Intervention	EO	2.972	0.383	0.03 (0.16)	
		EC	3.386	0.386	0.37 (1.83)*	0.39
	Maintenance	EO	4.016			
		EC	4.068			
4	Baseline	EO	3.316	0.524	0.42 (1.18)	
		EC	3.035	0.313	0.15 (0.43)	
	Intervention	EO	2.862	0.915	0.32 (1.47)	
		EC	3.103	0.651	0.27 (1.23)	

Table 3.7 continued

Participant	Phase	Condition	<i>M</i> (cm/s)	<i>SD</i>	<i>C</i> ( <i>Z</i> )	IRD
5	Baseline	EO	4.908	0.703	0.21 (0.59)	
		EC	3.843	0.443	0.18 (0.50)	
	Intervention	EO	3.948	0.567	0.41 (1.98)*	1.00
		EC	4.595	0.926	0.61 (2.92)*	1.00
	Maintenance	EO	3.500			
		EC	3.999			

*Note.* *C* = *C* statistic; *Z* = *Z* score; IRD = improvement rate difference

\**p* < .05

Table 3.8

*Time To Boundary Mean Minima Results*

Participant	Phase	Condition	<i>M</i> (s)	<i>SD</i>	<i>C</i> ( <i>Z</i> )	IRD
<i>Anterior-Posterior Direction</i>						
1	Baseline	EO	13.14	1.82	0.25 (0.72)	
		EC	12.48	1.20	0.30 (0.84)	
	Intervention	EO	13.11	1.80	0.17 (0.76)	
		EC	14.27	3.58	0.34 (1.55)	1.00**
	Maintenance	EO	17.59			
		EC	15.34			
2	Baseline	EO	8.18	1.45	0.50 (1.41)	
		EC	6.85	0.52	0.22 (0.63)	
	Intervention	EO	10.35	2.18	0.67 (3.21)*	1.00
		EC	8.61	1.48	0.33 (1.60)	1.00**
	Maintenance	EO	9.60			
		EC	18.80			
3	Baseline	EO	6.59	0.77	0.41 (1.12)	
		EC	4.97	0.80	0.17 (0.46)	
	Intervention	EO	6.28	1.45	0.05 (0.22)	
		EC	4.76	0.79	0.07 (0.35)*	
	Maintenance	EO	6.32			
		EC	3.80			
4	Baseline	EO	7.04	1.01	0.32 (0.90)	
		EC	7.49	1.54	0.50 (1.41)	
	Intervention	EO	7.68	1.46	0.14 (0.69)	
		EC	6.22	1.25	0.11 (0.52)	

Table 3.8 continued

Participant	Phase	Condition	<i>M</i> (s)	<i>SD</i>	<i>C</i> ( <i>Z</i> )	IRD
<i>Anterior-Posterior Direction continued</i>						
5	Baseline	EO	4.10	0.54	0.17 (0.48)	0.69
		EC	4.71	1.26	0.43 (1.18)	
	Intervention	EO	4.56	1.11	0.11 (0.53)	
		EC	3.84	0.83	0.47 (2.30)*	
	Maintenance	EC	3.65			
<i>Medial-Lateral Direction</i>						
1	Baseline	EO	21.96	4.43	0.50 (1.41)	1.00
		EC	17.86	1.26	0.33 (0.92)	
	Intervention	EO	23.00	3.58	0.22 (0.99)	
		EC	26.51	3.11	0.68 (3.07)*	
	Maintenance	EO	28.61			
2	Baseline	EO	14.24	1.79	0.18 (0.51)	1.00
		EC	13.09	2.55	0.47 (1.34)	
	Intervention	EO	17.60	5.51	0.51 (2.46)*	
		EC	15.87	4.00	0.65 (3.15)*	
	Maintenance	EO	15.00			
3	Baseline	EO	11.23	2.74	0.20 (0.54)	1.00
		EC	8.83	1.20	0.08 (0.21)	
	Intervention	EO	10.08	3.07	0.26 (1.24)	
		EC	8.28	2.14	0.10 (0.46)*	
	Maintenance	EO	8.36			
4	Baseline	EO	8.63	1.45	0.49 (1.37)	1.00
		EC	11.12	2.57	0.14 (0.39)	
	Maintenance	EO	6.57			



Table 3.8 continued

Participant	Phase	Condition	<i>M</i> (s)	<i>SD</i>	<i>C</i> ( <i>Z</i> )	IRD
<i>Medial-Lateral Direction continued</i>						
4 (cont)	Intervention	EO	11.50	3.21	0.29 (1.38)	0.60**
		EC	11.01	2.47	0.20 (0.97)	
5	Baseline	EO	5.17	0.87	0.02 (0.05)	0.38
		EC	7.32	1.70	0.64 (1.76)*	
	Intervention	EO	6.08	1.21	0.11 (0.54)	
		EC	5.53	1.44	0.60 (2.95)*	
	Maintenance	EC	4.12			

*Note.* *C*= *C* statistic; *Z*= *Z* score; IRD= improvement rate difference; EO= eyes open;

EC= eyes closed

\**p*< .05

\*\* based on SD bands

Table 3.9

*Time To Boundary Standard Deviation*

Participant	Phase	Condition	<i>M</i> (s)	<i>SD</i>	<i>C</i> (Z)	IRD
<i>Anterior-Posterior Direction</i>						
1	Baseline	EO	7.30	1.21	0.06 (0.17)	
		EC	8.55	2.87	0.41 (1.15)	
	Intervention	EO	7.86	1.52	0.24 (1.07)	
		EC	7.63	2.21	0.21 (0.94)	
	Maintenance	EO	11.53			
		EC	10.06			
2	Baseline	EO	6.10	1.34	0.50 (1.40)	
		EC	5.45	0.56	0.38 (0.27)	
	Intervention	EO	6.77	1.26	0.41 (1.96)*	0.22
		EC	6.04	1.08	0.27 (1.29)	1.00**
	Maintenance	EO	5.90			
		EC	5.95			
3	Baseline	EO	5.01	0.95	0.69 (1.89)*	
		EC	3.52	0.47	0.66 (1.80)*	
	Intervention	EO	7.47	1.72		
		EC	3.79	0.99		
	Maintenance	EO	4.49			
		EC	2.74			
4	Baseline	EO	4.63	0.71	0.38 (1.07)	
		EC	6.64	2.08	0.05 (0.15)	
	Intervention	EO	5.48	1.09	0.09 (0.44)	
		EC	4.64	1.26	0.13 (0.61)	
5	Baseline	EO	3.45	0.35	0.08 (0.23)	
		EC	4.07	0.89	0.62 (1.71)*	

Table 3.9 continued

Participant	Phase	Condition	<i>M</i> (s)	<i>SD</i>	<i>C</i> ( <i>Z</i> )	IRD
<i>Anterior-Posterior Direction continued</i>						
5 (cont)	Intervention	EO	3.53	0.82	0.10 (0.47)	0.69
		EC	3.06	0.86	0.62 (1.71)*	
	Maintenance	EC	3.10			
<i>Medial-Lateral Direction</i>						
1	Baseline	EO	11.24	2.74	0.17 (0.46)	1.00
		EC	8.83	1.20	0.08 (0.21)	
	Intervention	EO	10.08	3.07	0.19 (0.95)	
		EC	8.28	2.14	0.40 (1.95)*	
	Maintenance	EO	8.36			
		EC	6.57			
2	Baseline	EO	10.27	0.82	0.49 (1.39)	1.00**
		EC	8.35	2.15	0.21 (0.58)	
	Intervention	EO	11.69	2.45	0.30 (1.43)	
		EC	10.65	1.73	0.11 (0.51)	
	Maintenance	EO	8.54			
		EC	13.04			
3	Baseline	EO	7.89	2.68	0.13 (0.36)	1.00**
		EC	7.37	1.36	0.21 (0.57)	
	Intervention	EO	7.47	1.72	0.17 (0.83)	
		EC	6.17	1.69	0.07 (0.32)	
	Maintenance	EO	5.01			
		EC	4.48			
4	Baseline	EO	6.34	0.70	0.37 (0.00)	1.00**
		EC	8.50	1.68	0.04 (0.10)	
	Intervention	EO	8.49	2.79	0.00 (0.02)	
		EC	8.42	3.59	0.16 (0.75)	

Table 3.9 continued

Participant	Phase	Condition	<i>M</i> (s)	<i>SD</i>	<i>C</i> ( <i>Z</i> )	IRD
<i>Medial-Lateral Direction continued</i>						
5	Baseline	EO	3.74	0.59	0.19 (0.51)	
		EC	5.60	0.98	0.20 (0.53)	
	Intervention	EO	4.65	1.17	0.07 (0.35)	
		EC	4.34	1.25	0.50 (2.48)*	0.69
	Maintenance	EC	2.60			

*Note.* *C*= *C* statistic; *Z*= *Z* score; IRD= improvement rate difference; EO= eyes open; EC= eyes closed

\**p*< .05

\*\*based on SD bands

Table 3.10

*Timed Up and Go Results*

Participant	Phase	<i>M</i> (s)	<i>SD</i>	<i>C</i> ( <i>Z</i> )	IRD
1	Baseline	5.49	0.46	0.16 (0.46)	
	Intervention	5.34	0.64	0.19 (0.68)	
	Maintenance	4.78			
2	Baseline	6.40	0.85	0.68 (1.85) <sup>a*</sup>	
	Intervention	6.87	1.02	0.58 (2.11)*	1.00
	Maintenance	4.85			
3	Baseline	6.23	0.50	0.31 (0.86)	
	Intervention	6.01	0.59	0.22 (0.84)	
	Maintenance	6.91			
4	Baseline	5.65	0.13	0.45 (1.26)	
	Intervention	6.74	0.54	0.39 (1.39)	0.52
	Maintenance	5.97			
5	Baseline	5.58	0.48	0.43 (1.17)	
	Intervention	6.38	0.76	0.34 (1.23)	
	Maintenance	5.38			

*Note.* *C* = *C* statistic; *Z* = *Z* score; IRD = improvement rate difference

<sup>a</sup>Opposite direction of desired

\**p* < .05

Table 3.11

*Gait Velocity Results*

Participant	Phase	<i>M</i> (m/s)	<i>SD</i>	<i>C</i> ( <i>Z</i> )	IRD
1	Baseline	1.17	0.13	0.29 (0.81)	
	Intervention	1.160	0.22	0.37 (1.31)	
	Maintenance	1.41			
2	Baseline	0.92	0.05	0.52 (1.43)	
	Intervention	1.06	0.26	0.67 (2.46)*	0.61
	Maintenance	1.48			
3	Baseline	1.08	0.11	0.24 (0.68)	
	Intervention	1.27	0.10	0.54 (2.05)*	0.17
	Maintenance	1.15			
4	Baseline	1.23	0.05	0.50 (1.41)	
	Intervention	1.08	0.17	0.35 (1.24)	
	Maintenance	1.15			
5	Baseline	1.24	0.11	0.035 (0.10)	
	Intervention	1.42	0.17	0.12 (0.45)	
	Maintenance	1.71			

*Note.* *C* = *C* statistic; *Z* = *Z* score; IRD = improvement rate difference

\**p* < .05

Table 3.12

*Hip Abductor Strength Results*

Participant	Phase	Side	<i>M</i> (lb)	<i>SD</i>	<i>C</i> ( <i>Z</i> )	IRD
1	Baseline	Right	13.7	2.0	0.25 (0.71)	
	Intervention	Right	11.0	2.3	0.26 (0.91)	
	Maintenance	Right	20.0			
2	Baseline	Right	7.6	0.3	-0.33 (-0.91)	
	Intervention	Right	10.8	3.3	0.56 (2.04)*	0.11
	Maintenance	Right	11.5			
3	Baseline	Left	10.9	3.2	0.39 (1.11)	
	Intervention	Left	17.3	3.7	0.67 (2.53)*	0.31
	Maintenance	Left	15.0			
4	Baseline	Left	14.7	2.8	0.79 (2.25)*	
	Intervention	Left	19.9	2.7		
	Maintenance	Left				
5	Baseline	Right	17.4	3.0	0.60 (1.66)*	
	Intervention	Right	17.0	0.9		
	Maintenance	Right	22.0			

Note. *C* = *C* statistic; *Z* = *Z* score; IRD = improvement rate difference

\**p* > .05

Table 3.13

*Activities Scale for Kids, Performance Version Results*

Participant	Phase	<i>M</i>	<i>SD</i>	IRD
1	Baseline	58.7		
	Intervention	97.3	1.0	
	Maintenance	96.4		
2	Baseline	77.7		
	Intervention	83.9	9.4*	1.00
	Maintenance	80.4		
3	Baseline	68.3		
	Intervention	74.8	4.5*	1.00
	Maintenance	80.4		
4	Baseline	85.0		
	Intervention	80.8	1.7	
5	Baseline	63.3		
	Intervention	73.9	3.0*	1.00
	Maintenance	73.3		

*Note.* IRD = improvement rate difference

\**SD* > 1.73 is a significant change



Figure 3.1

*Hip Abductor Strength Testing Position*



Figure 3.2

*Baseline phase procedures for participants 1 and 4*

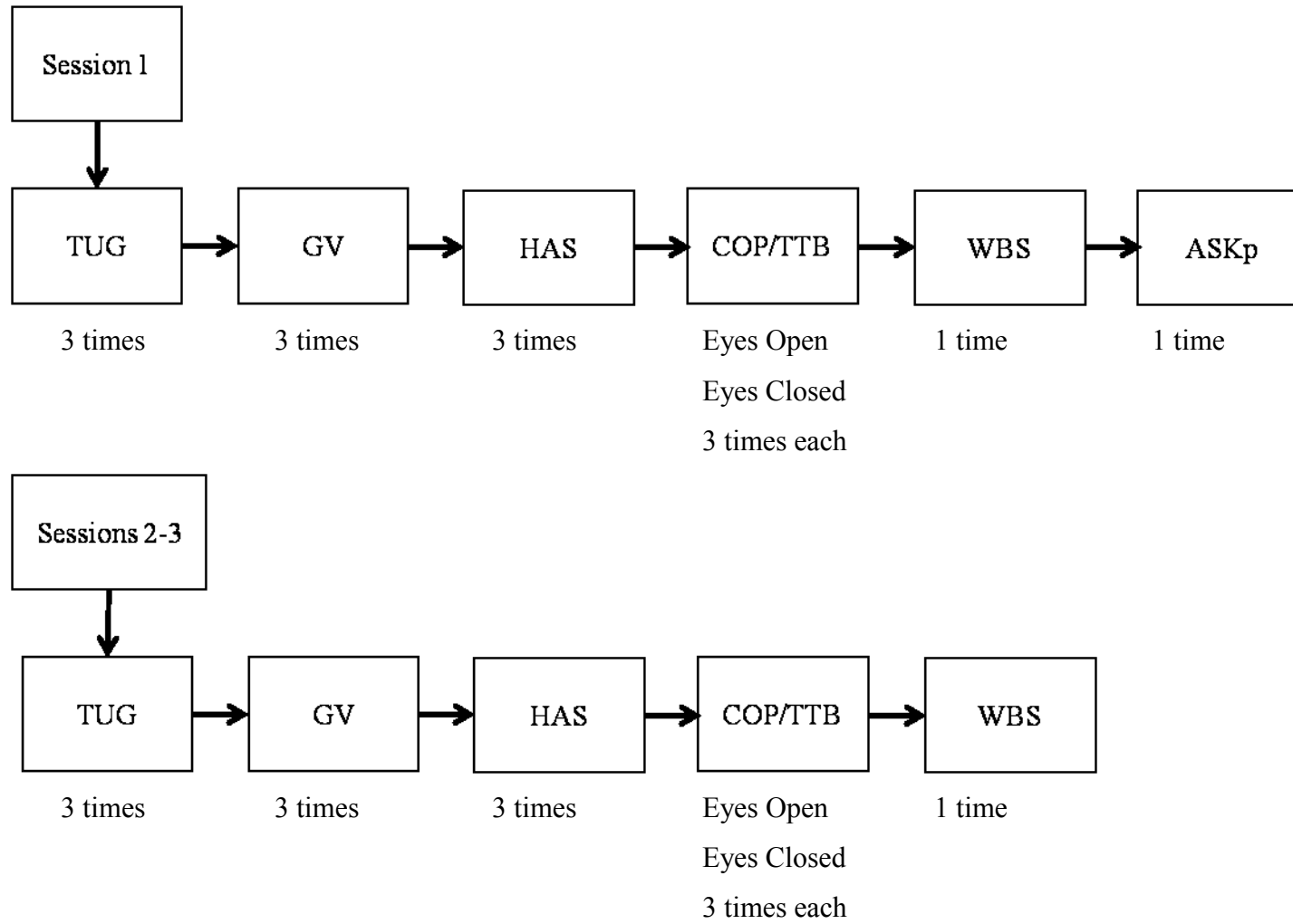


Figure 3.3

*Intervention phase for participants 1 and 4*

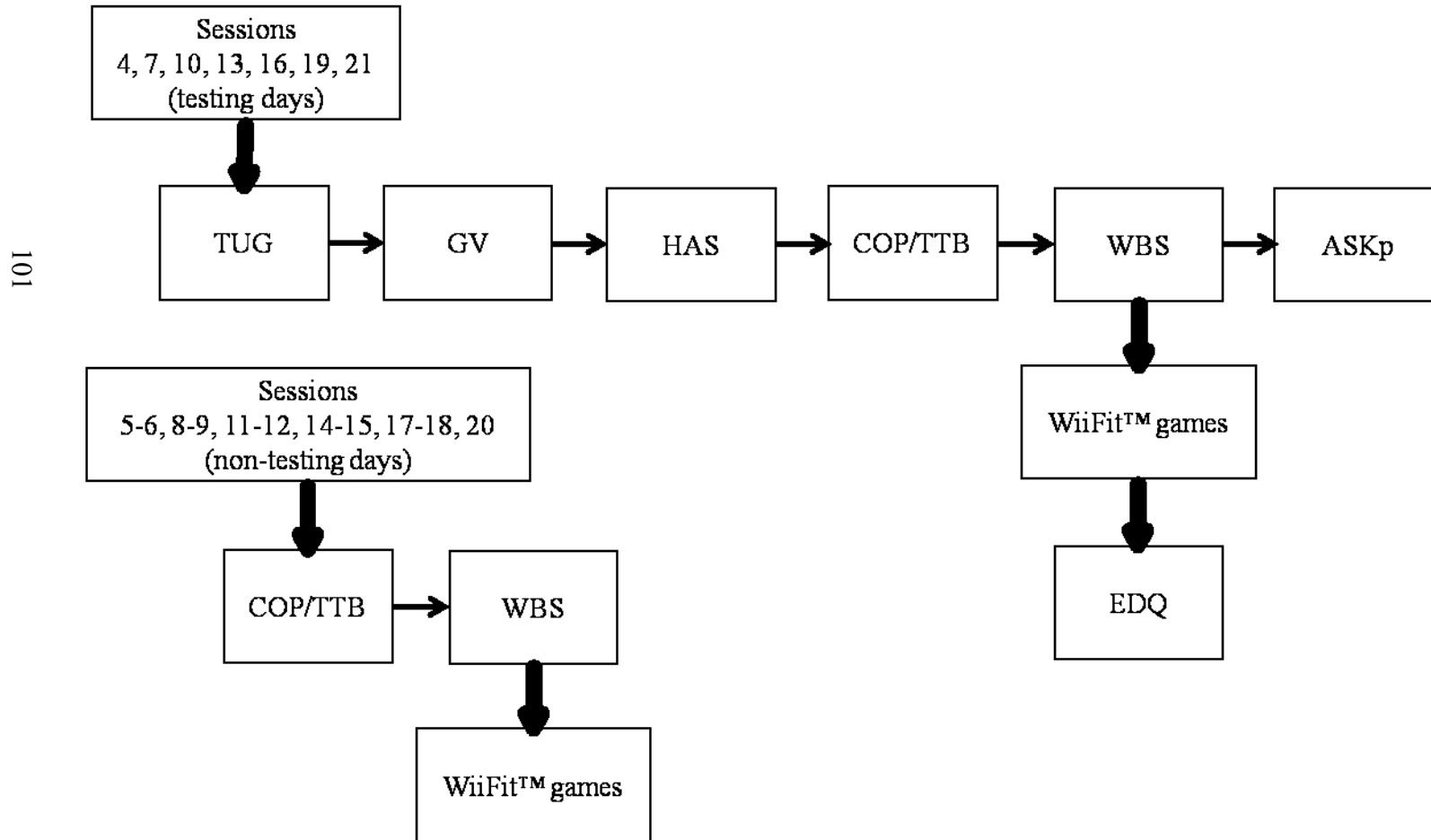


Figure 3.4

Screen shots of the lateral movement games



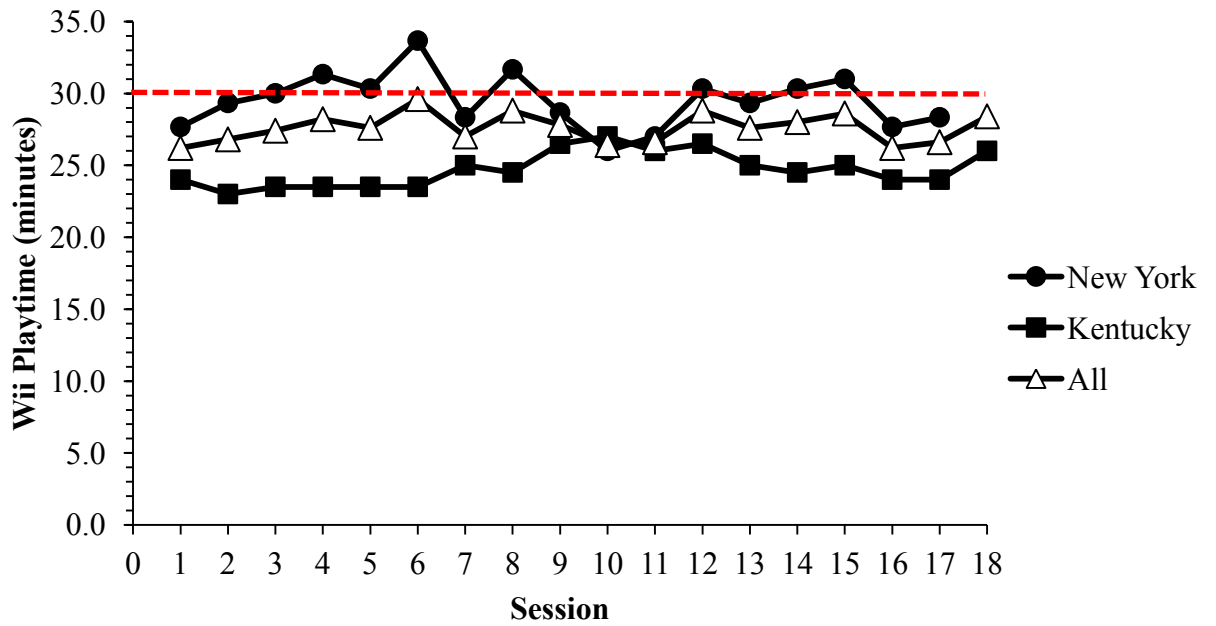
Figure 3.5

Screen shots of the multi-directional games



Figure 3.6

*Average Wii Playtime*



*Note.* The red dashed line was the goal (30 minutes) for each session.

Figure 3.7

*Average number of rest breaks for all participants*

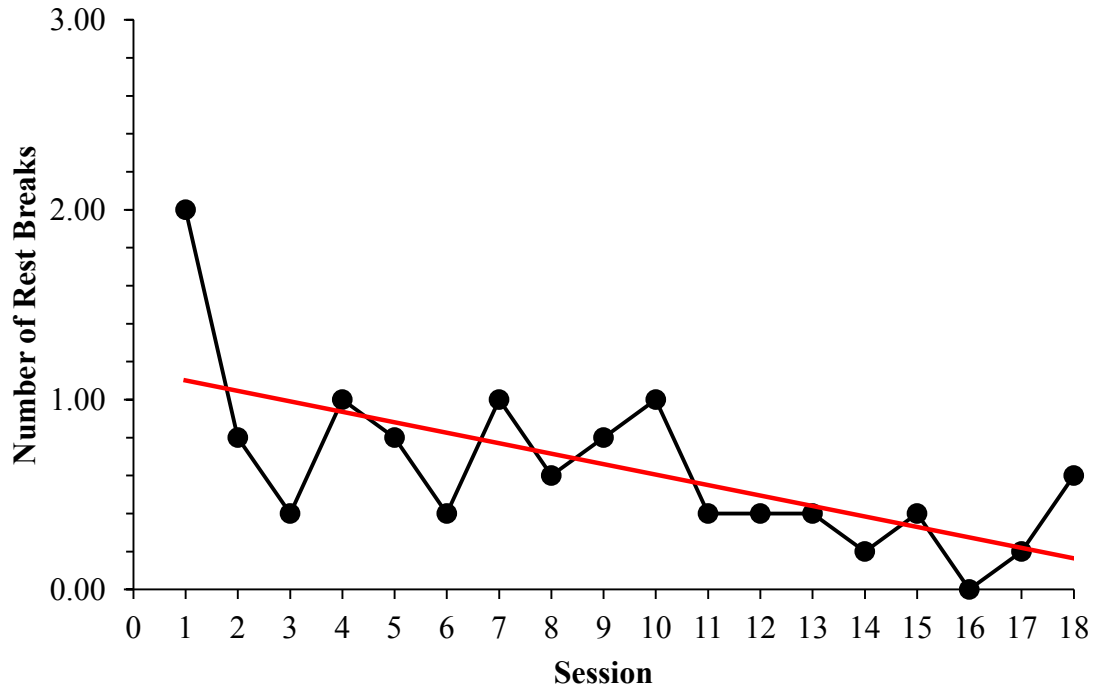




Figure 3.8

*Average Number of Requests to Change Activities*

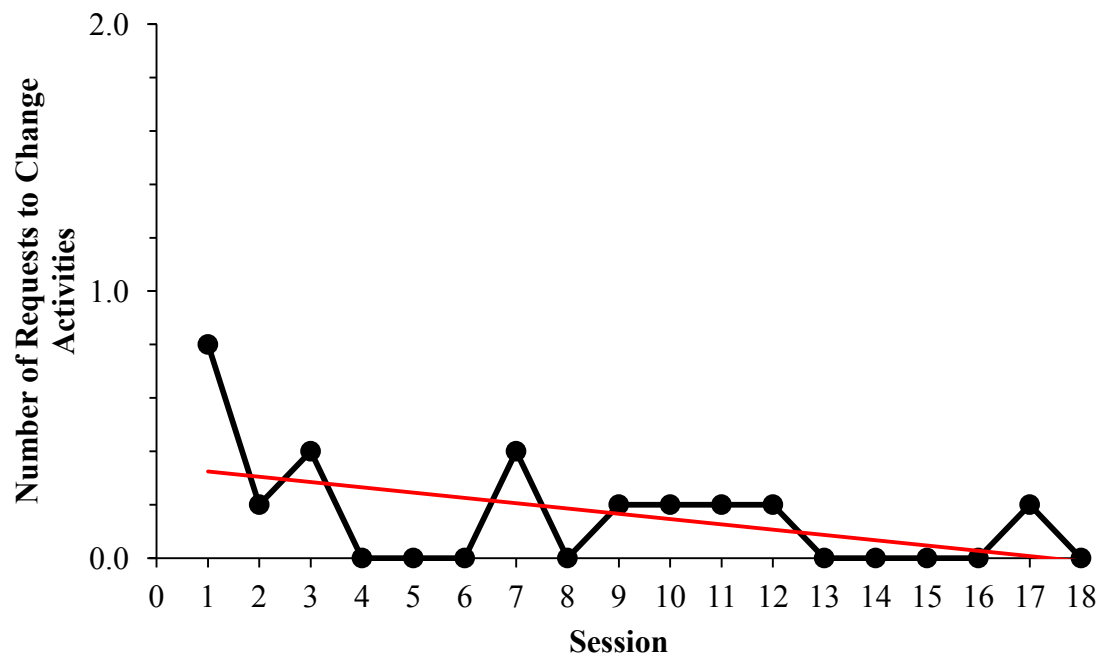




Figure 3.9

Results of Weight Bearing Symmetry

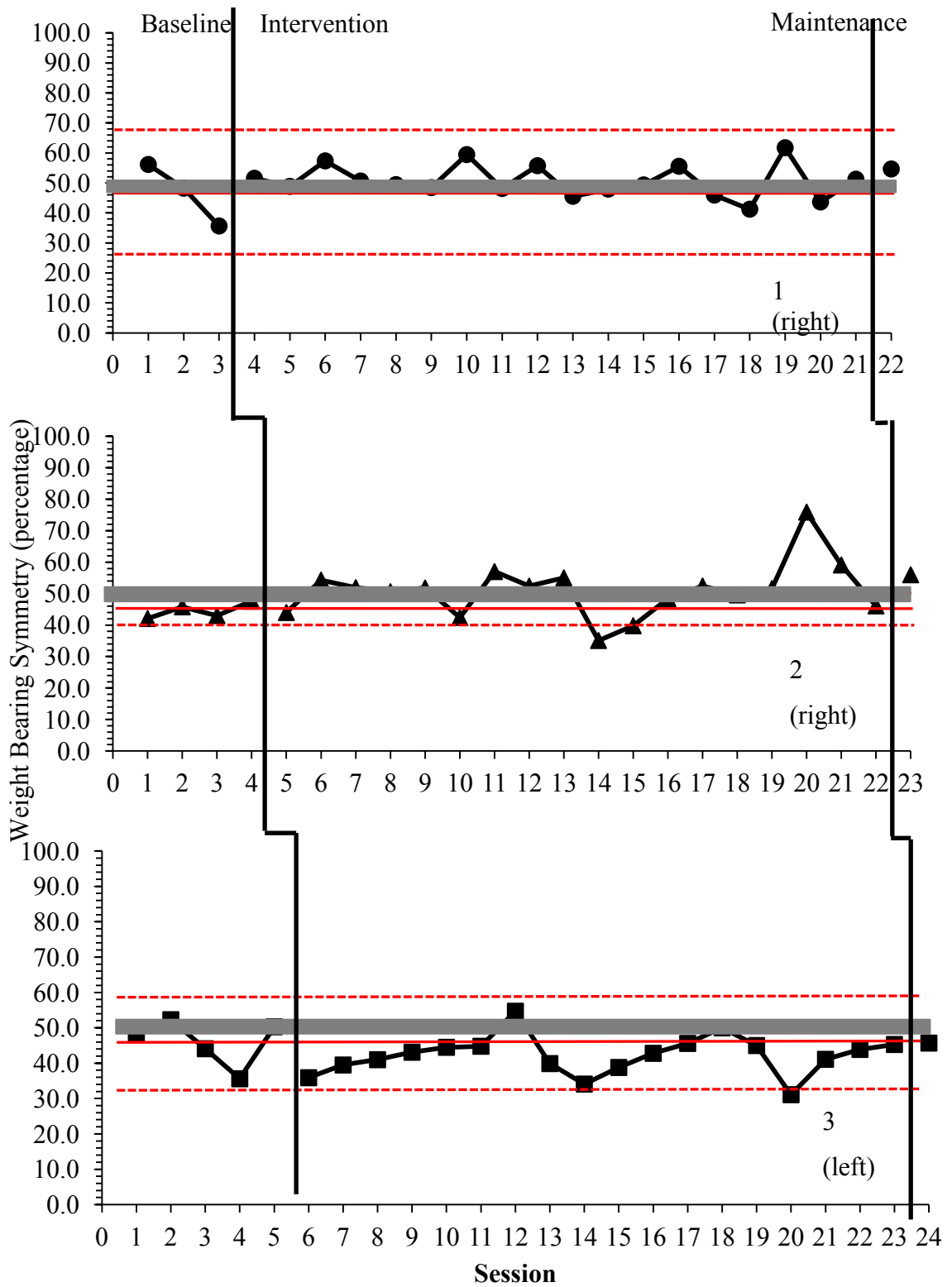
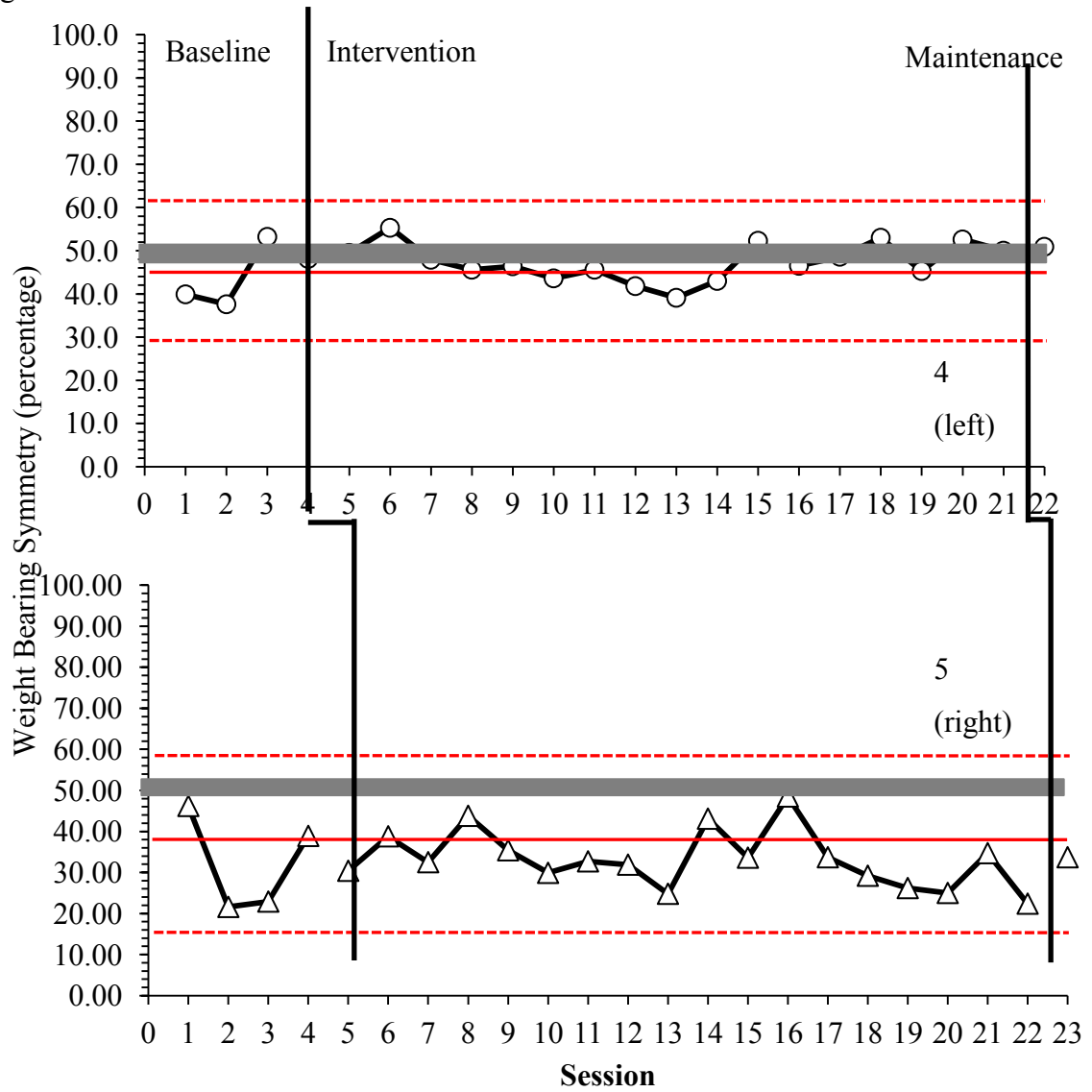


Figure 3.9 continued



Note. The gray bar represents the goal range of 48-52%.

Figure 3.10

Center of Pressure Area Eyes Open Results

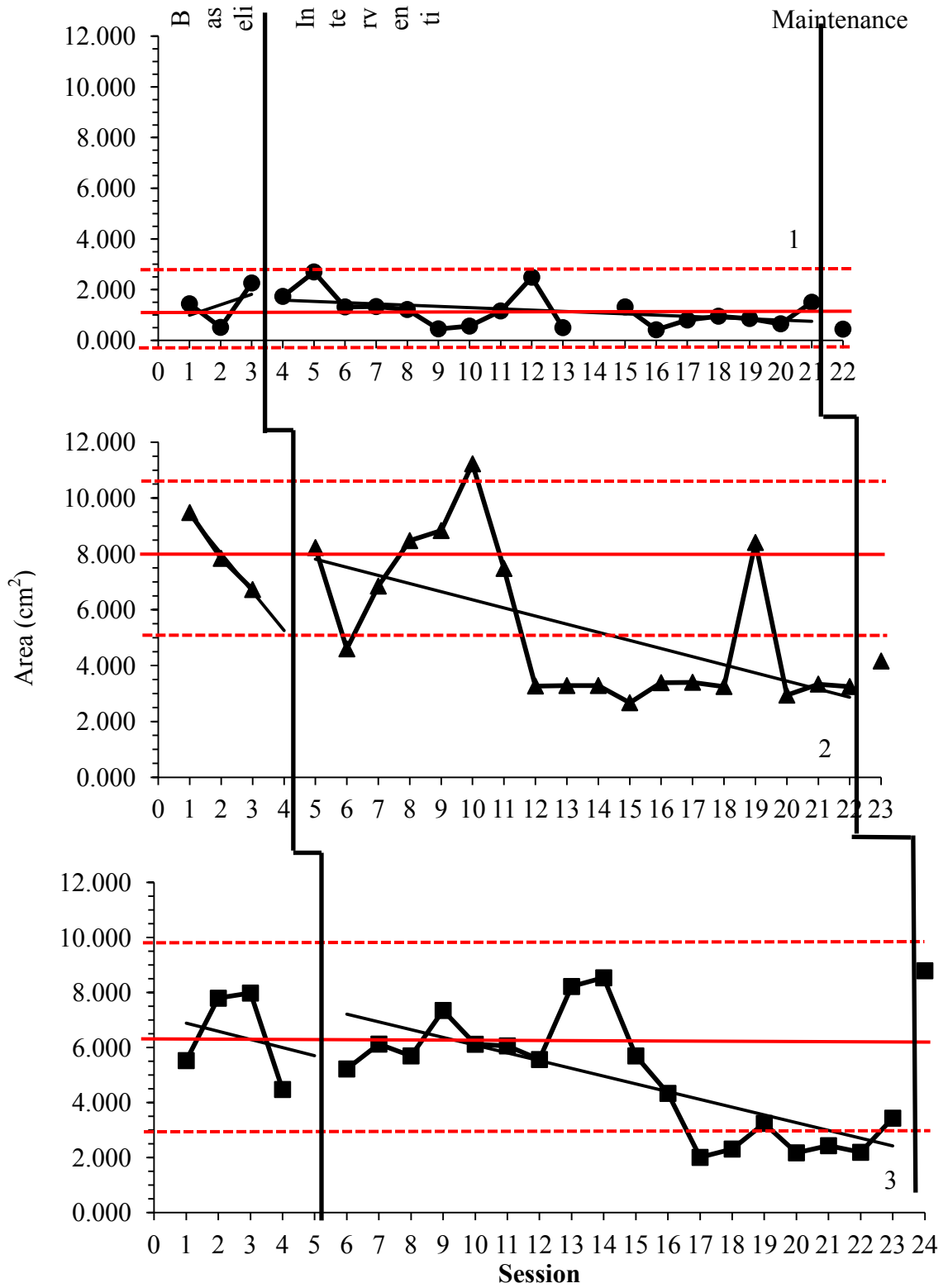


Figure 3.10 continued

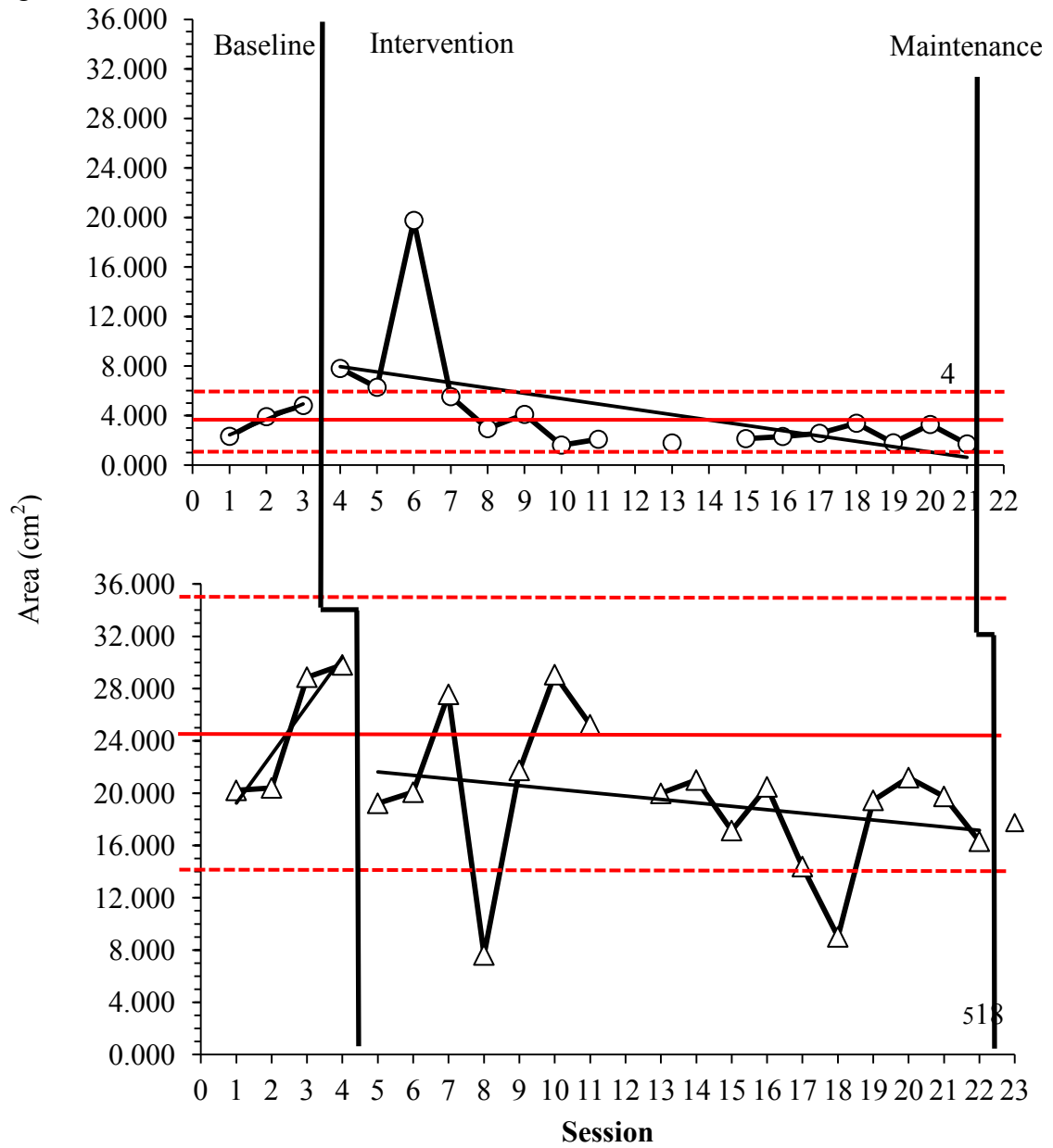


Figure 3.11

Center of Pressure Area Eyes Closed Results

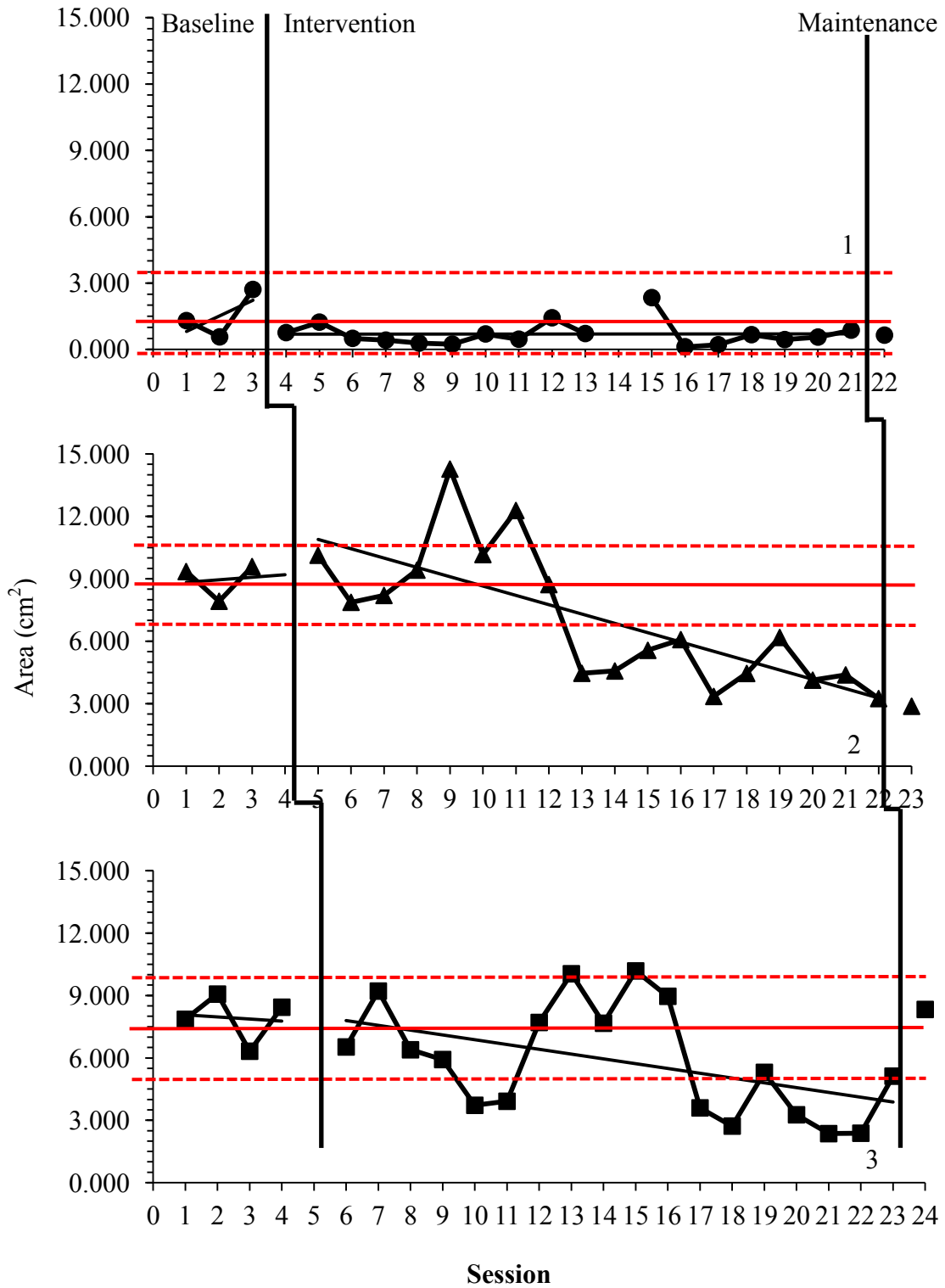
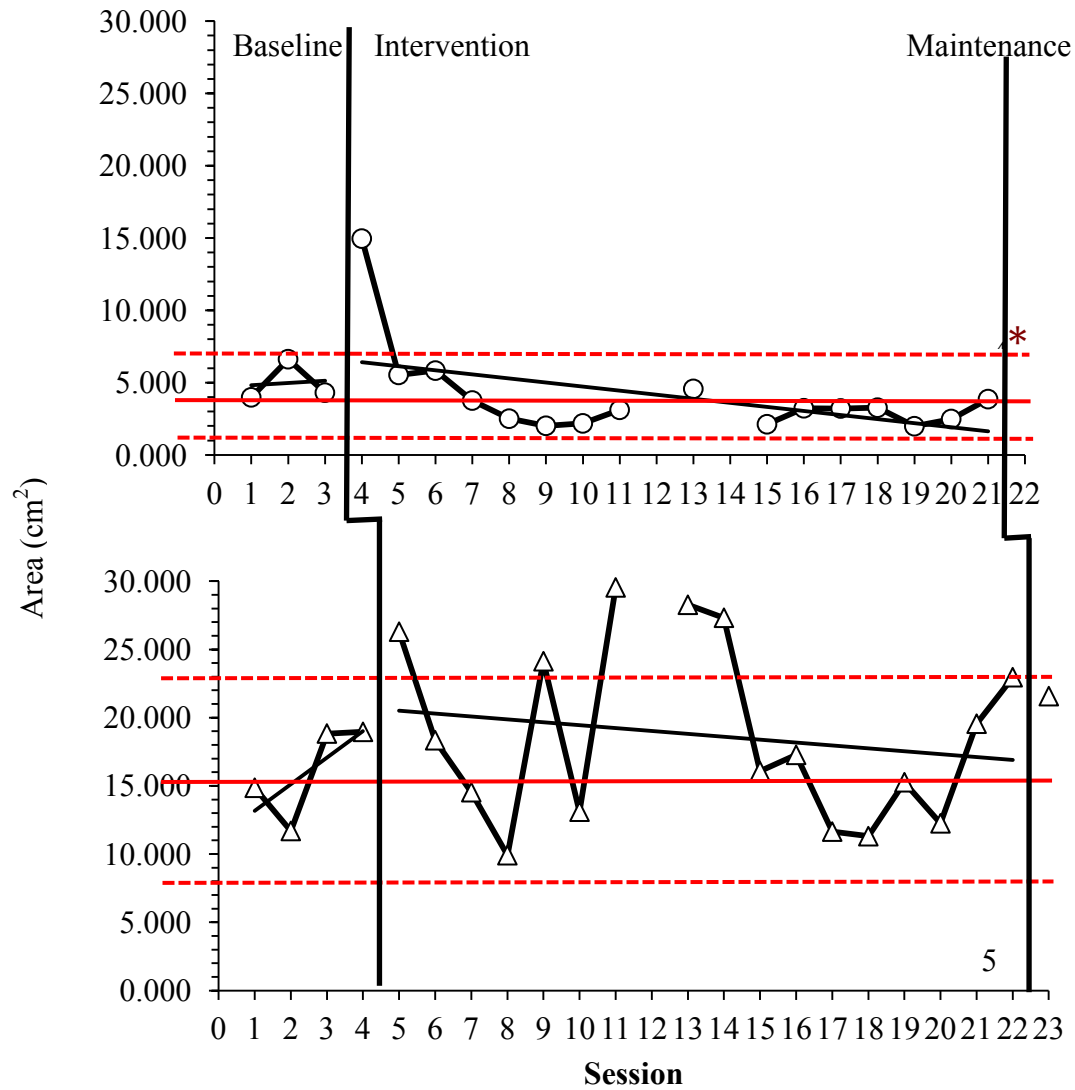


Figure 3.11 continued



Note. Participants 4 and 5 have larger scales on the y axis.

Figure 3.12

Center of Pressure Velocity Eyes Open Results

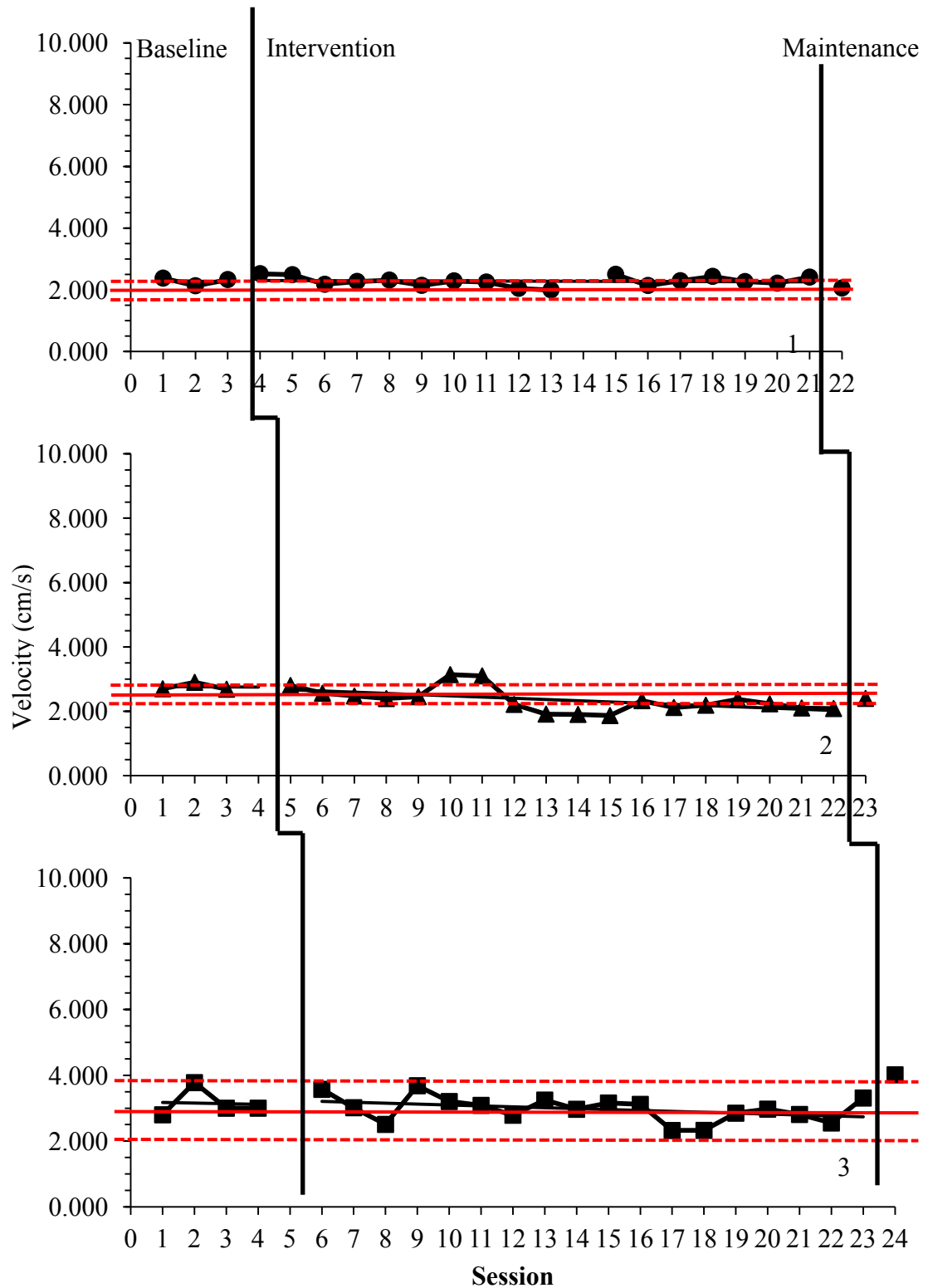


Figure 3.12 continued

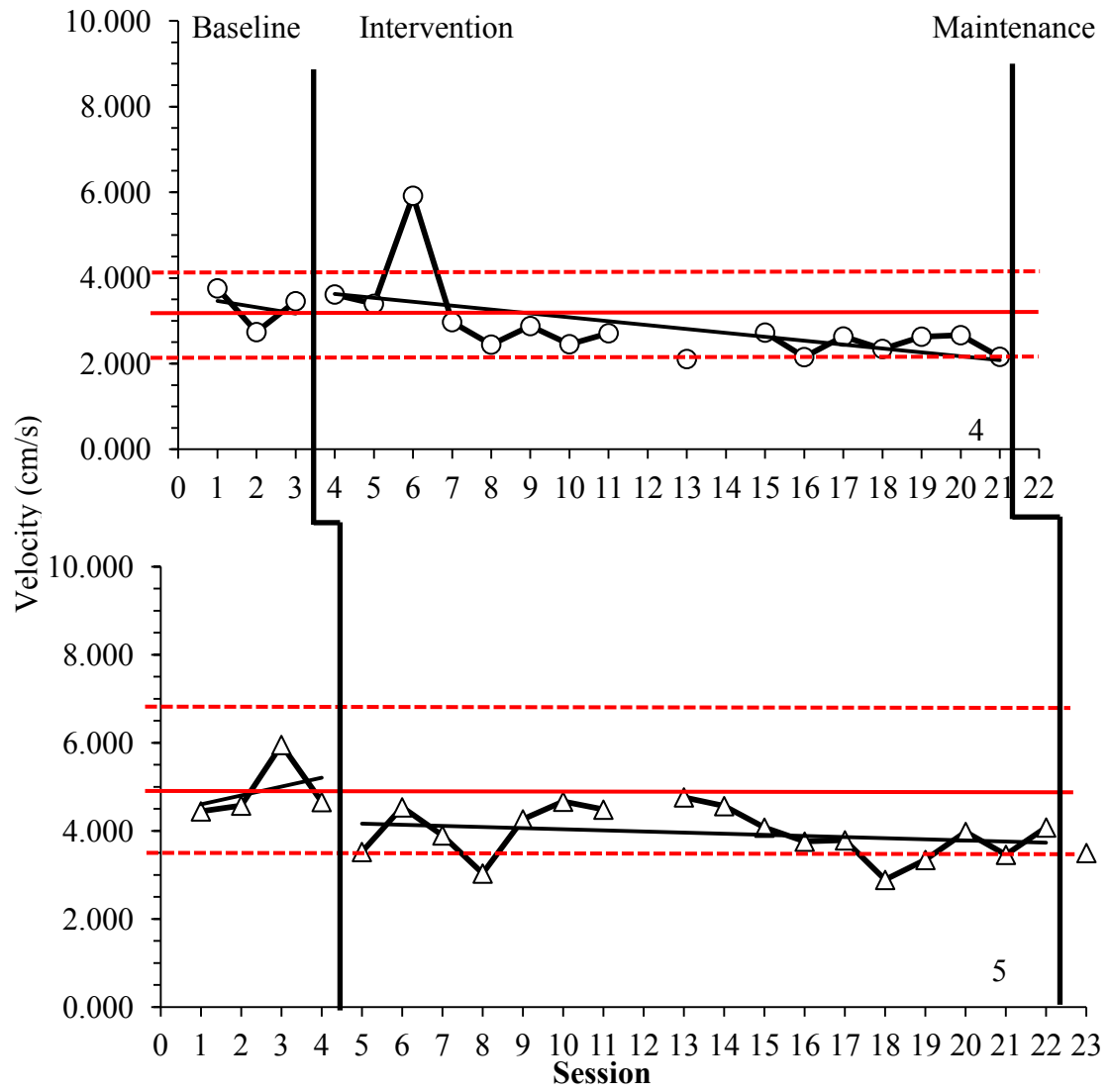




Figure 3.13

Center of Pressure Velocity Eyes Closed Results

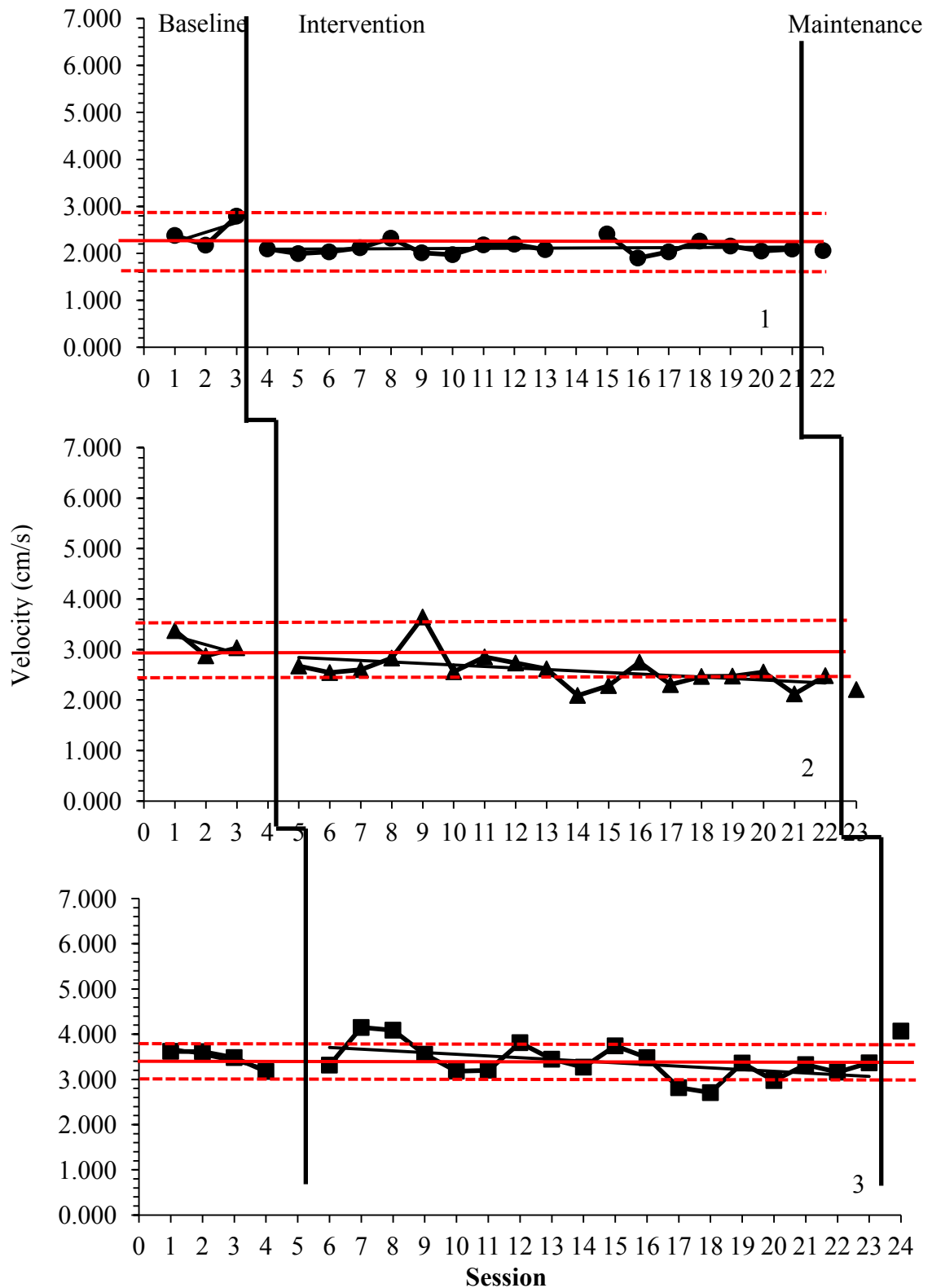


Figure 3.13 continued

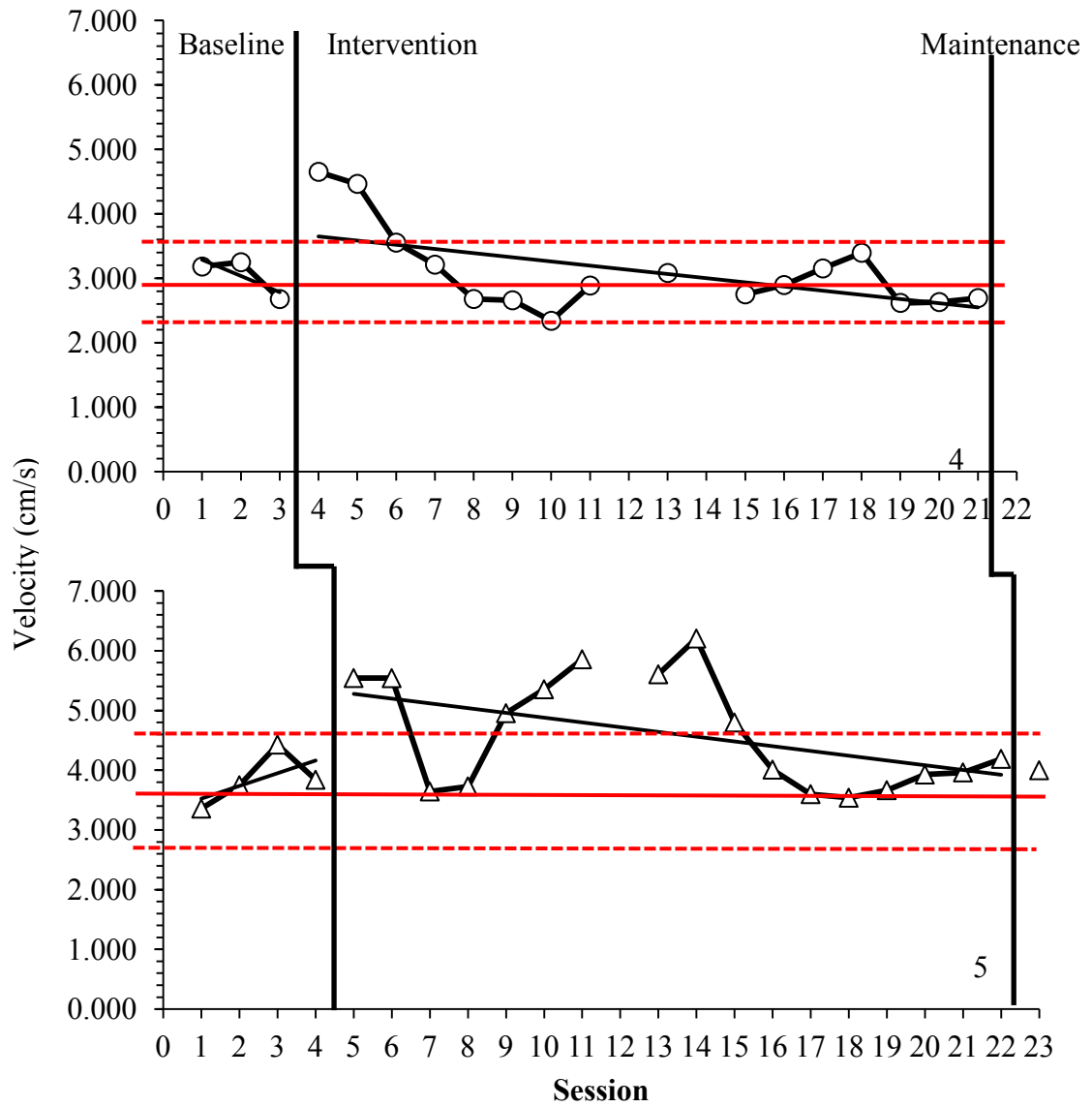


Figure 3.14

*Time To Boundary Mean Minima, Anterior Posterior with Eyes Open*

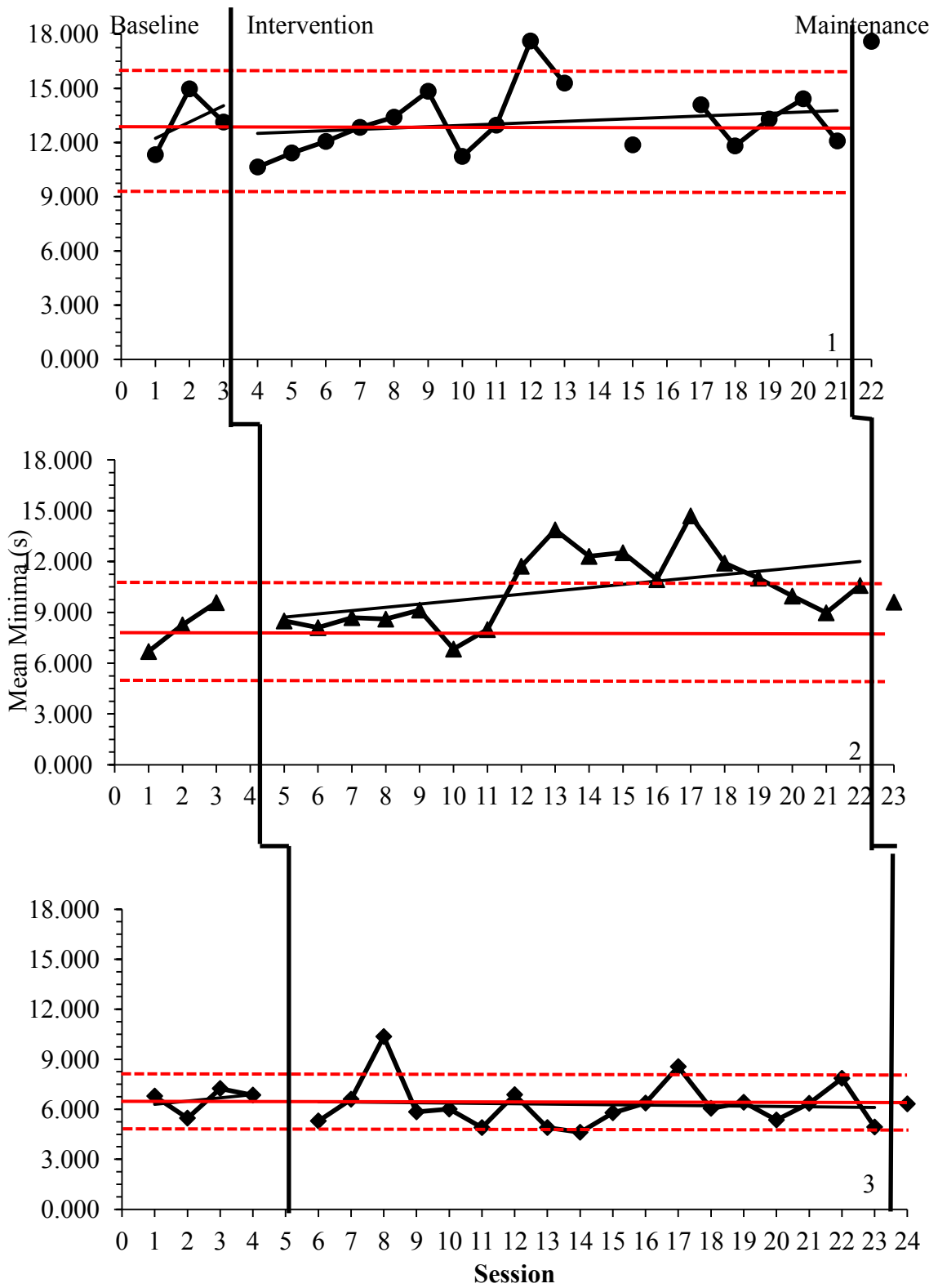


Figure 3.14 continued

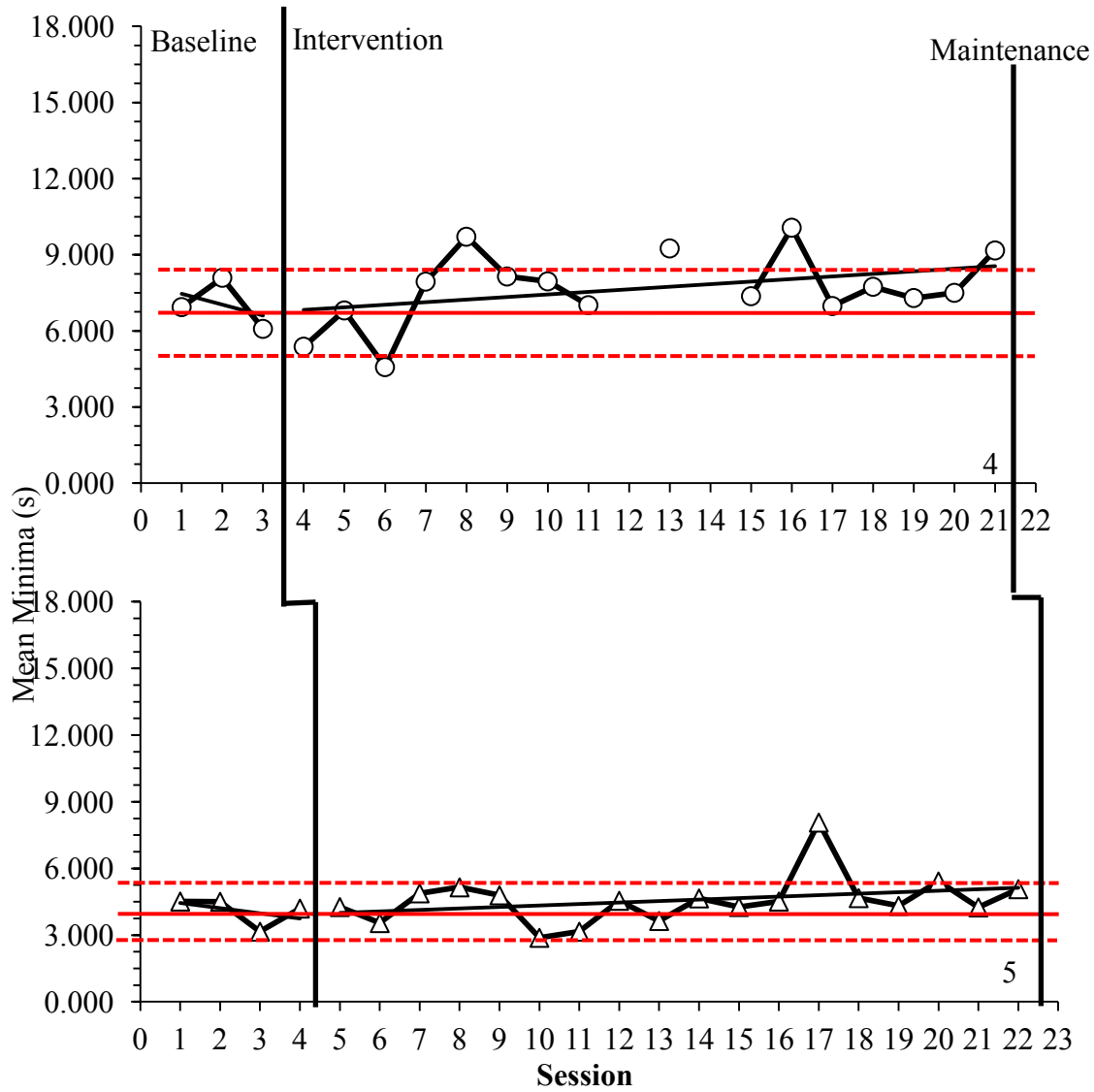


Figure 3.15

*Time to Boundary Mean Minima, Anterior Posterior with Eyes Closed*

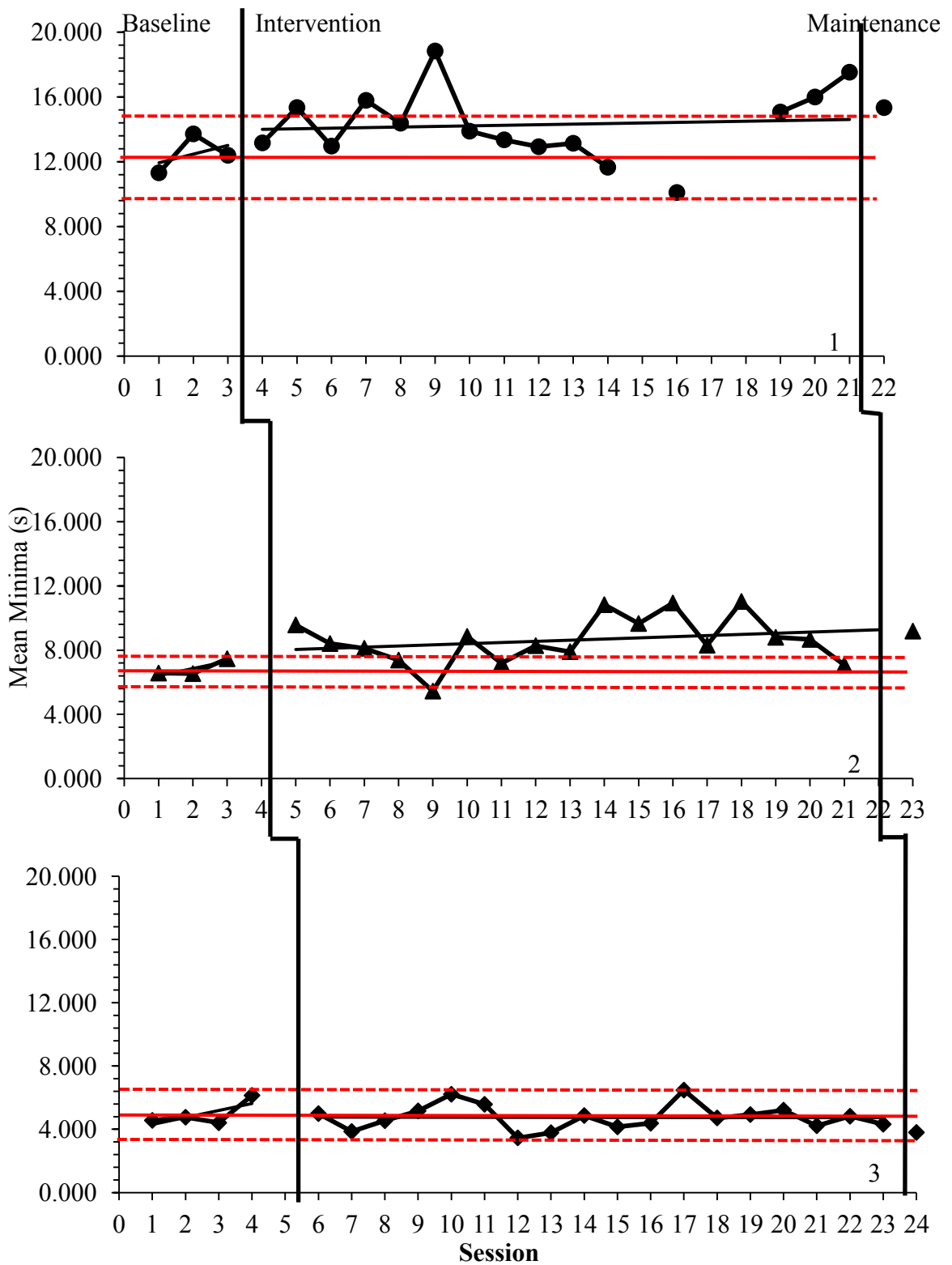


Figure 3.15 continued

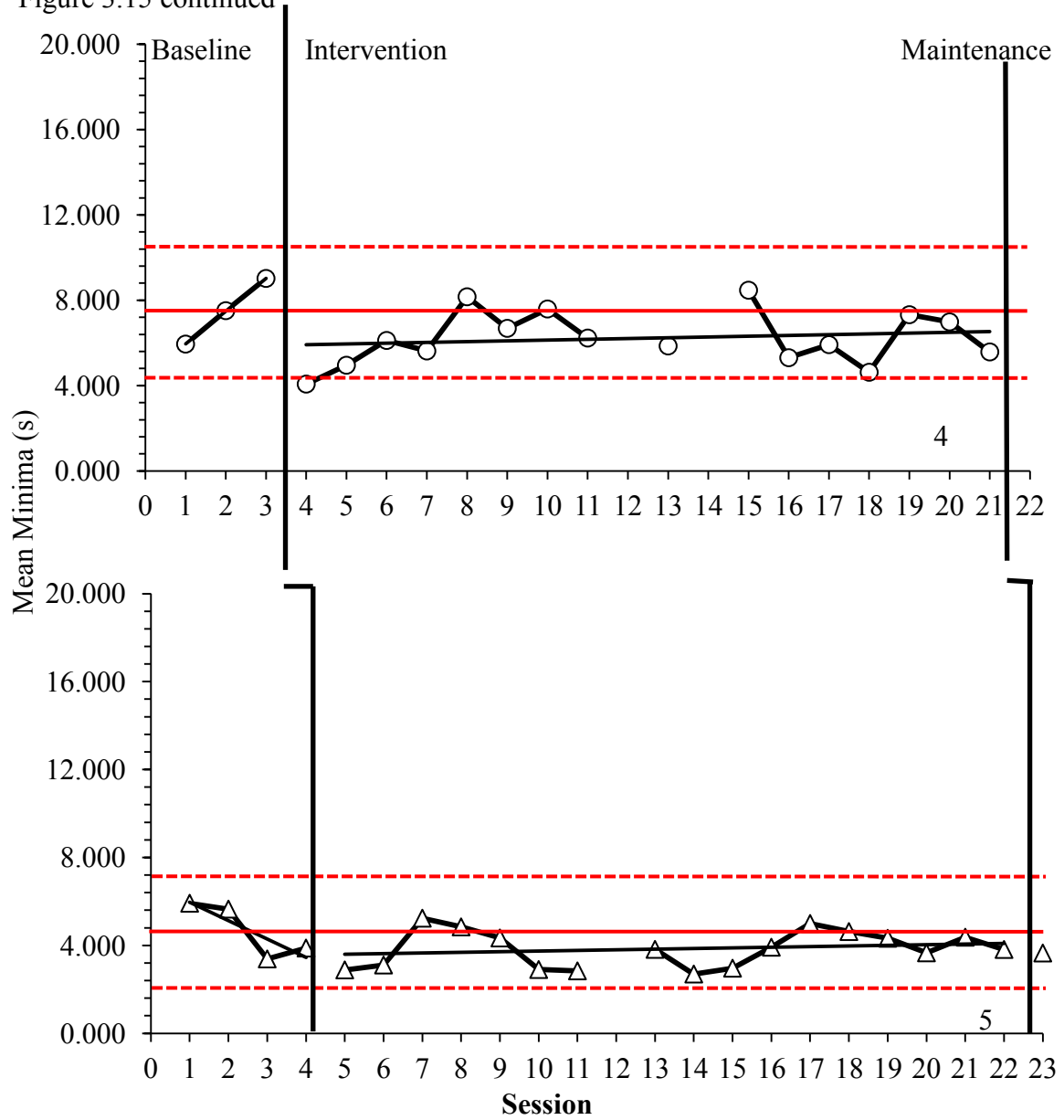


Figure 3.16

*Time To Boundary Mean Minima, Medial Lateral with Eyes Open*

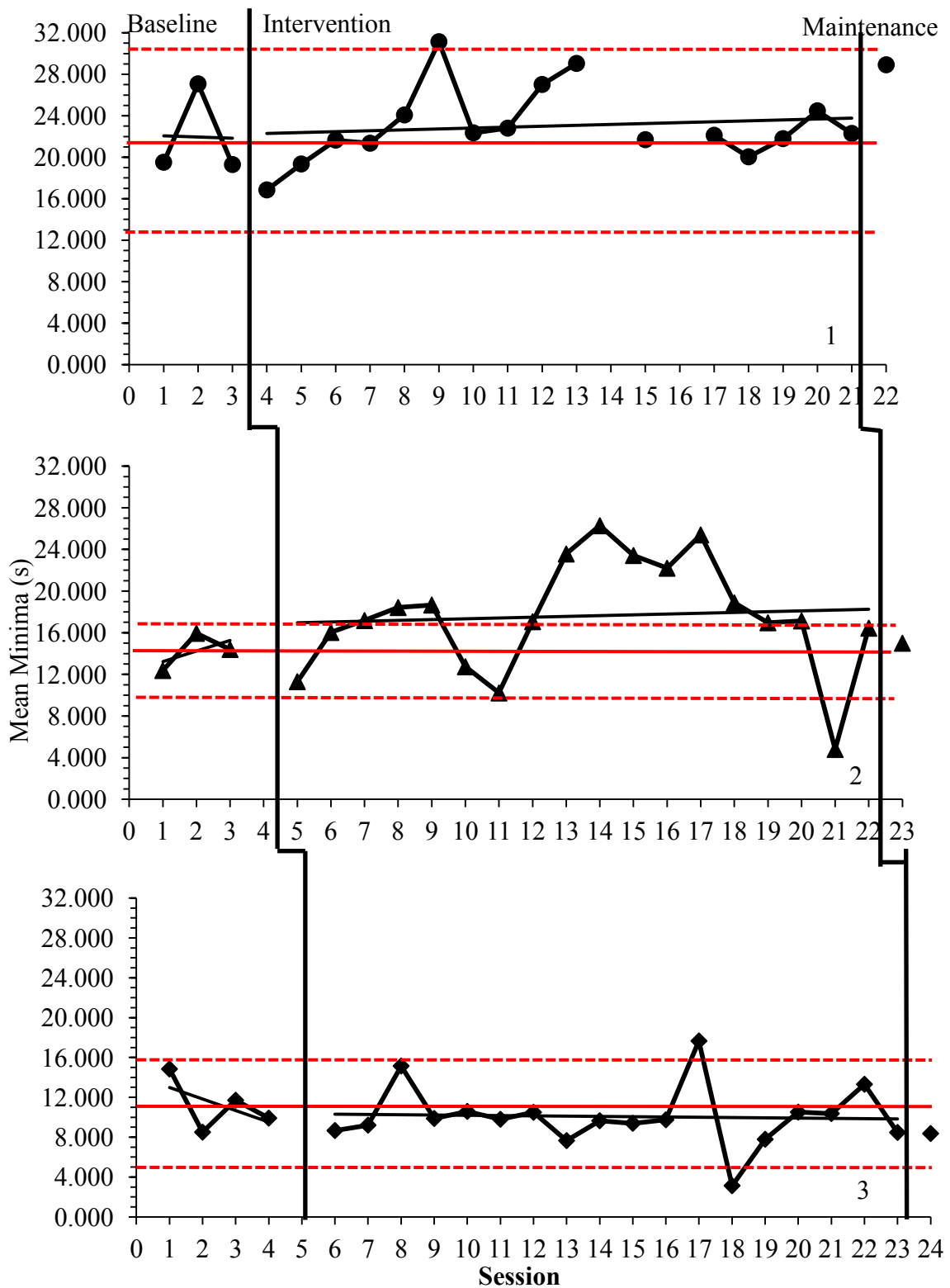


Figure 3.16 continued

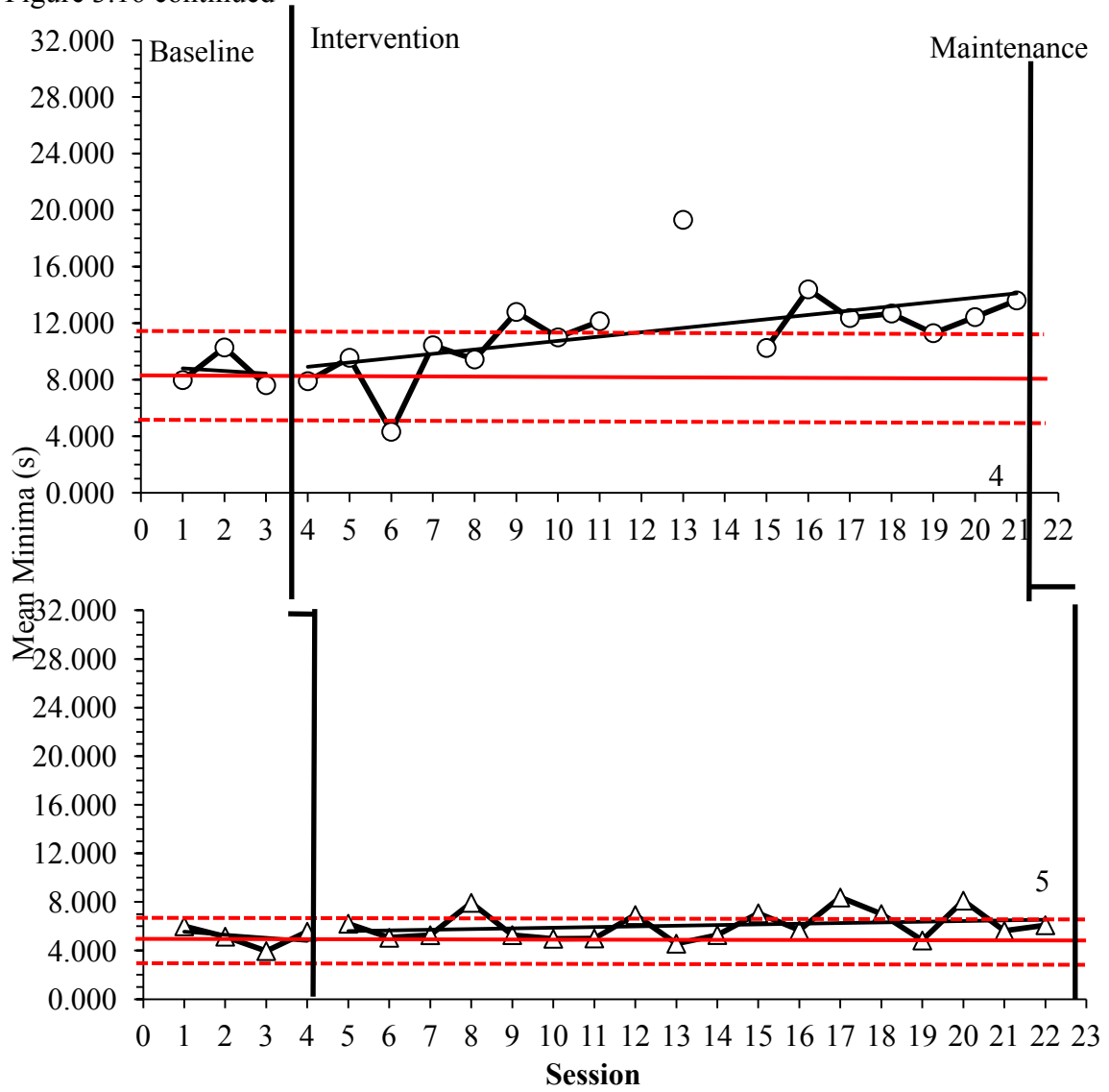




Figure 3.17

*Time To Boundary Mean Minima, Medial Lateral Eyes Closed Condition.*

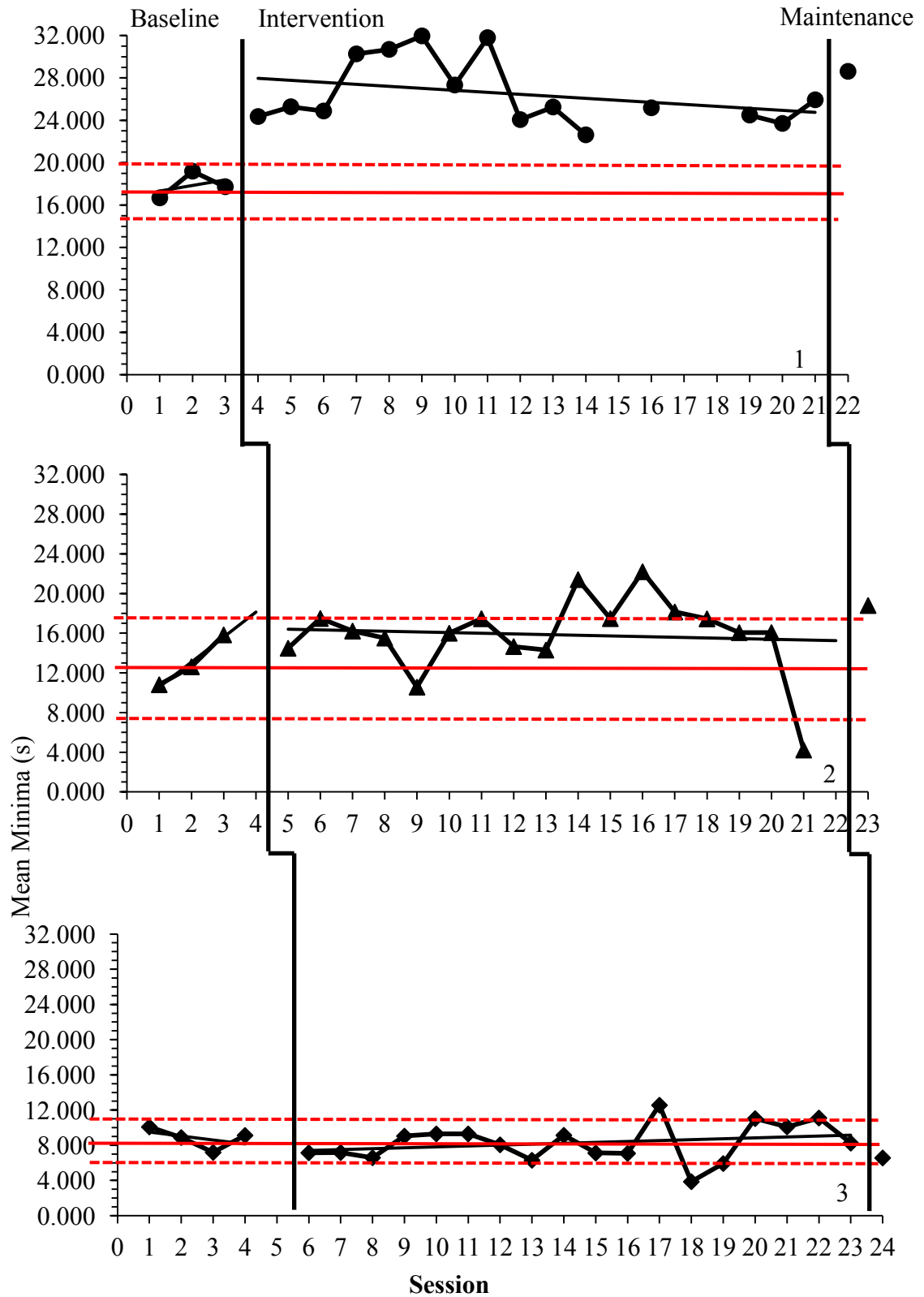


Figure 3.17 continued

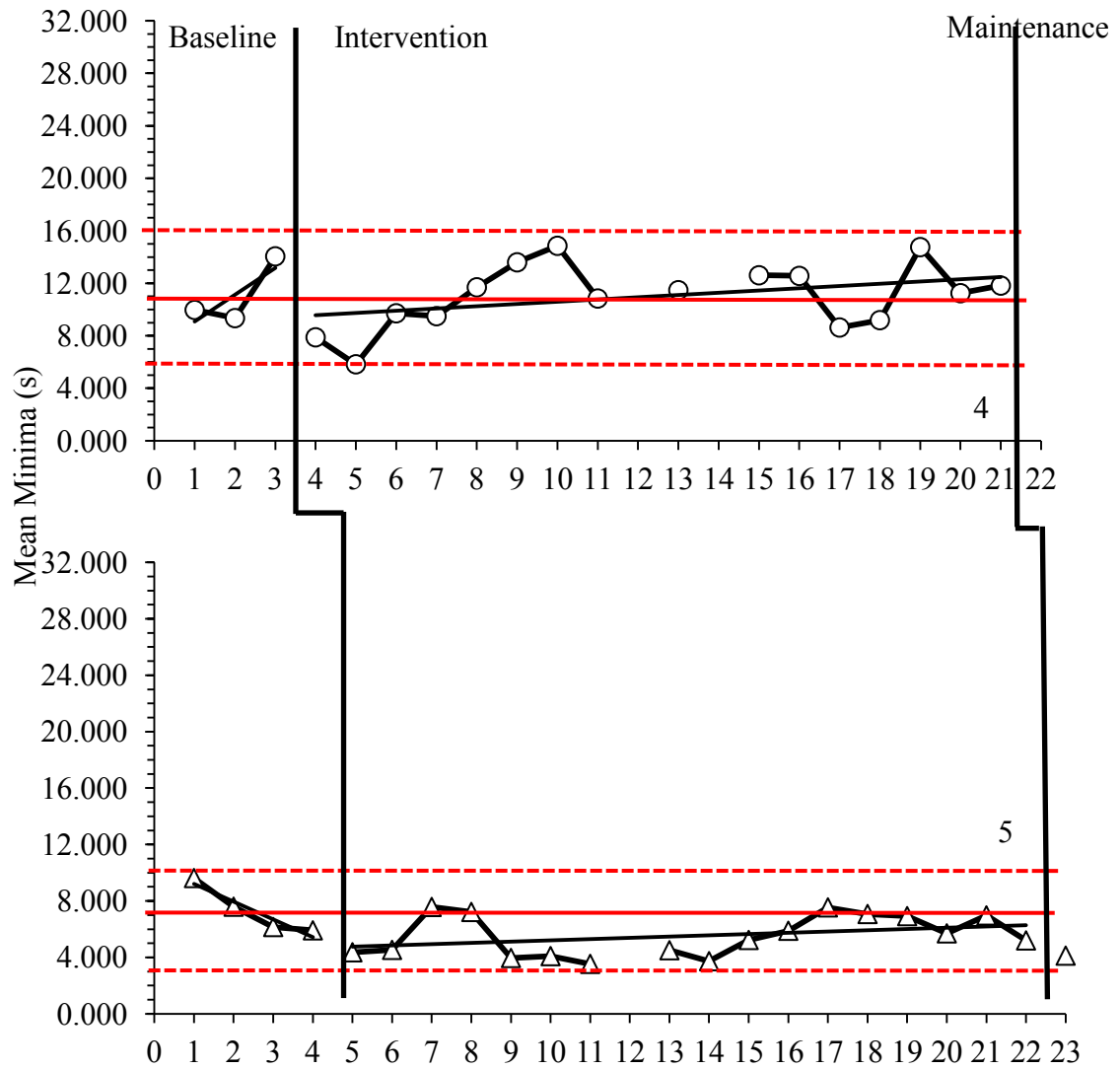


Figure 3.18

*Time To Boundary Standard Deviation, Anterior Posterior Direction with Eyes Open*

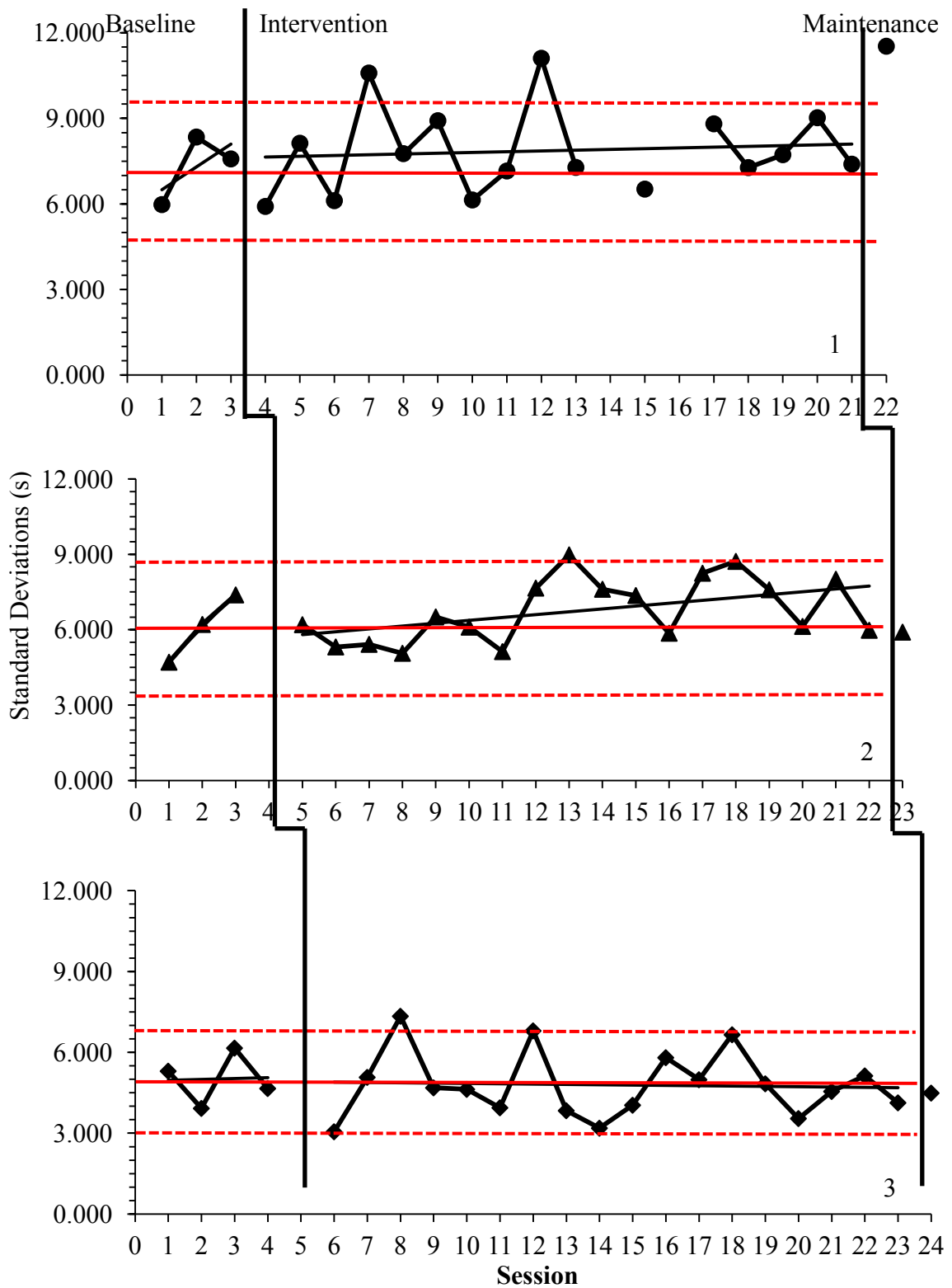


Figure 3.18 continued

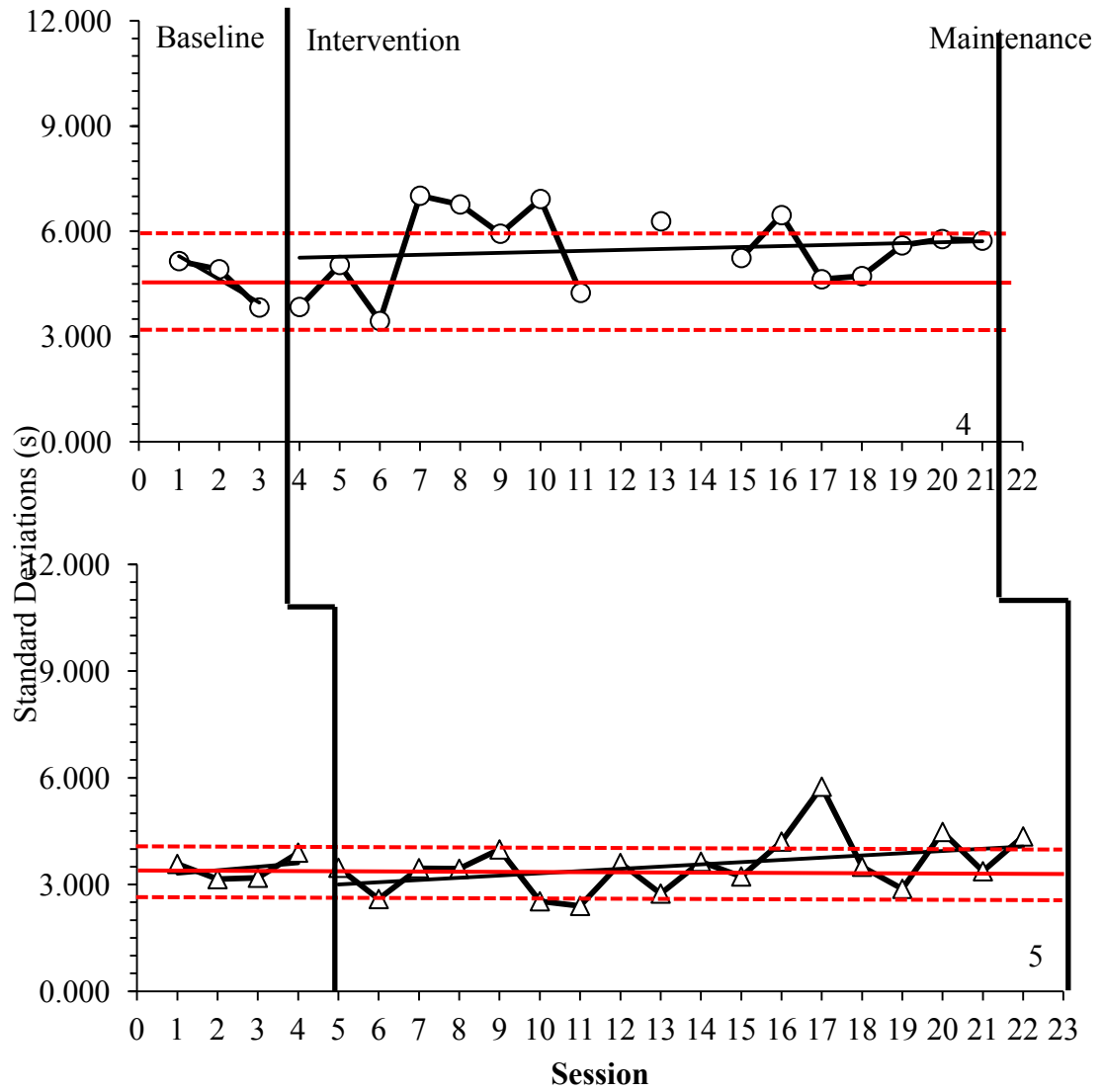


Figure 3.19

*Time To Boundary Standard Deviation, Anterior-Posterior direction with Eyes Closed*

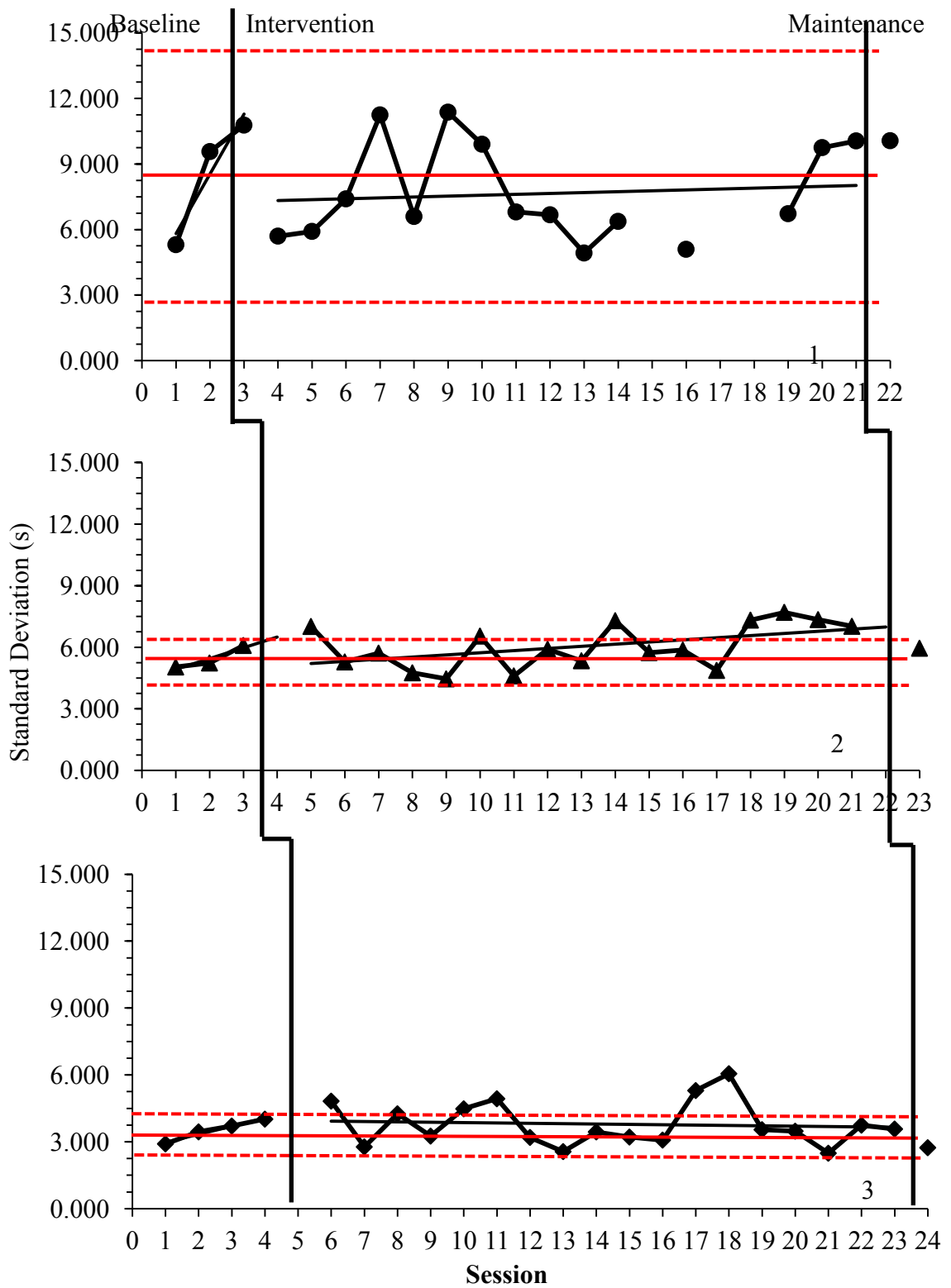


Figure 3.19 continued

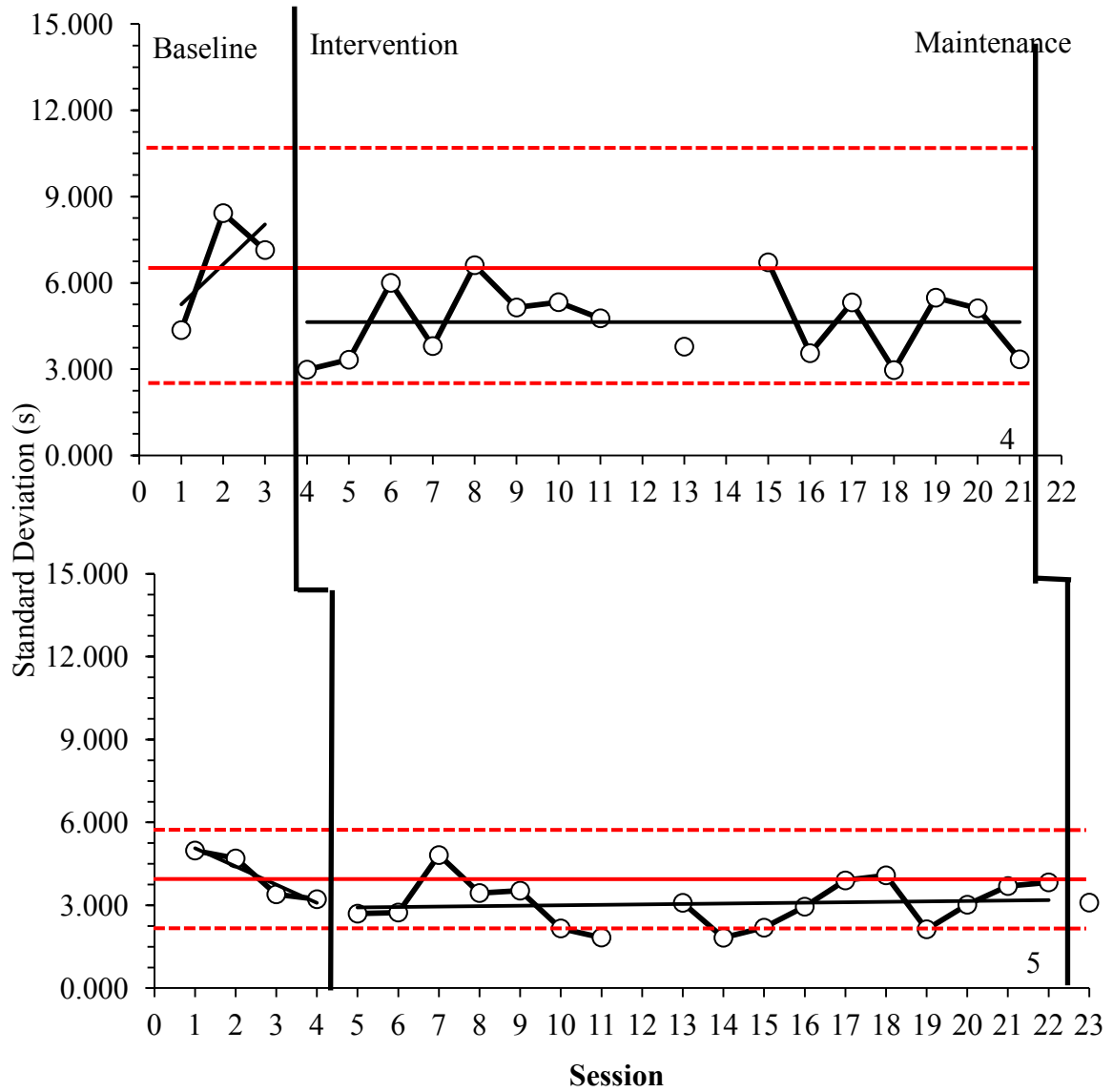


Figure 3.20

*Time To Boundary Standard Deviation for the Medial Lateral Direction with Eyes Open*

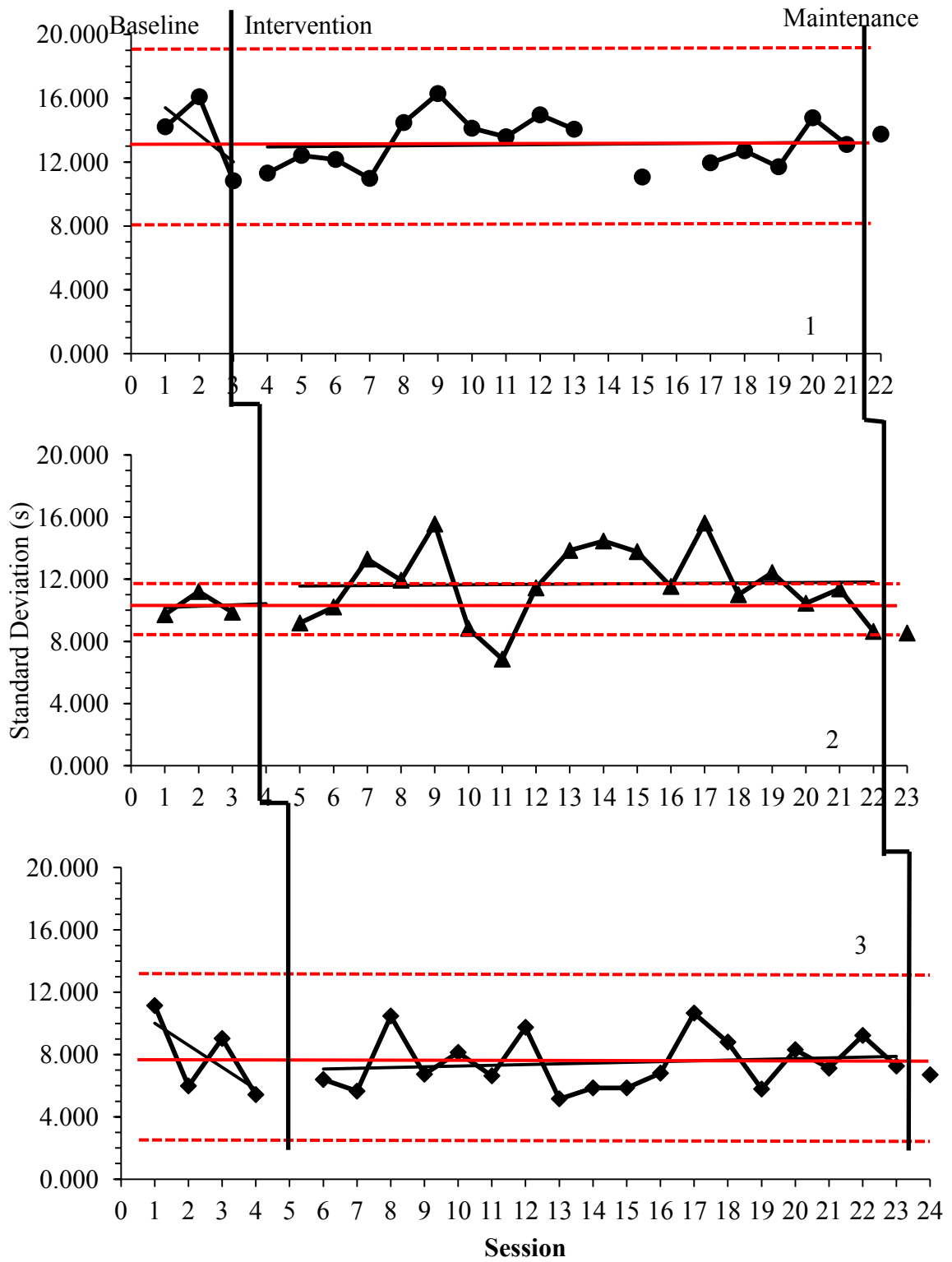


Figure 3.20 continued

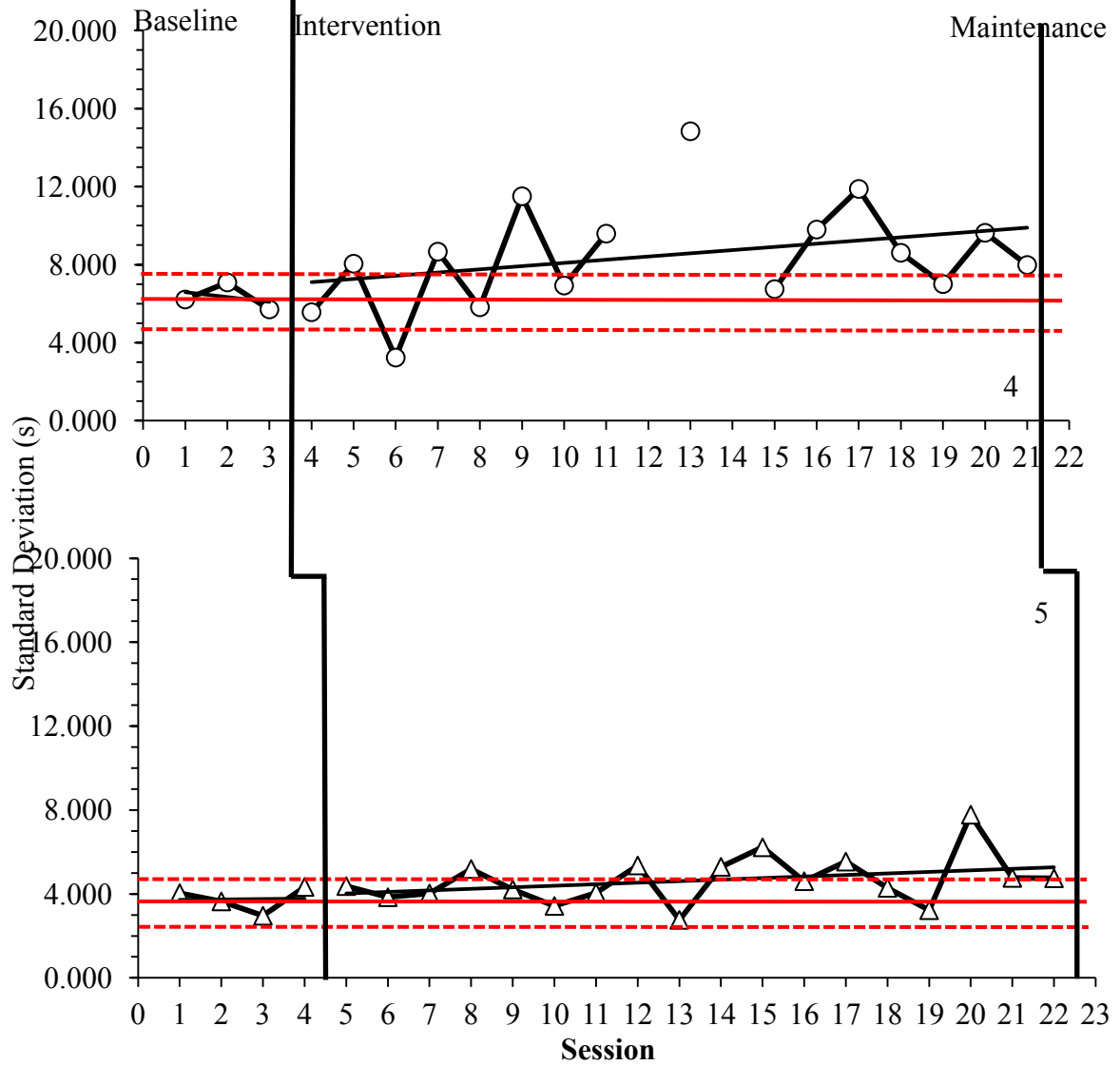




Figure 3.21

*Time To Boundary Standard Deviation in the Medial Lateral direction with Eyes Closed*

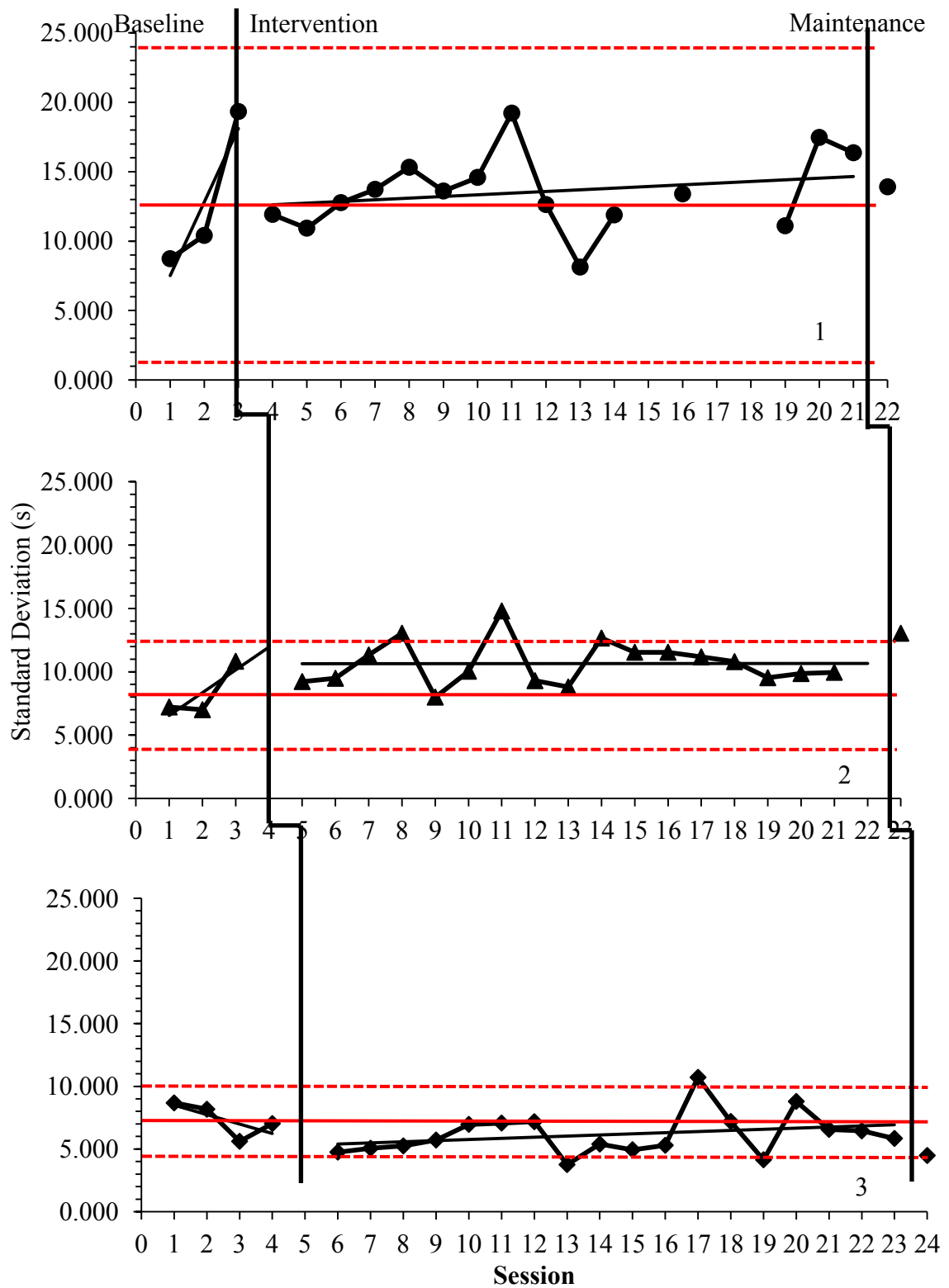


Figure 3.21 continued

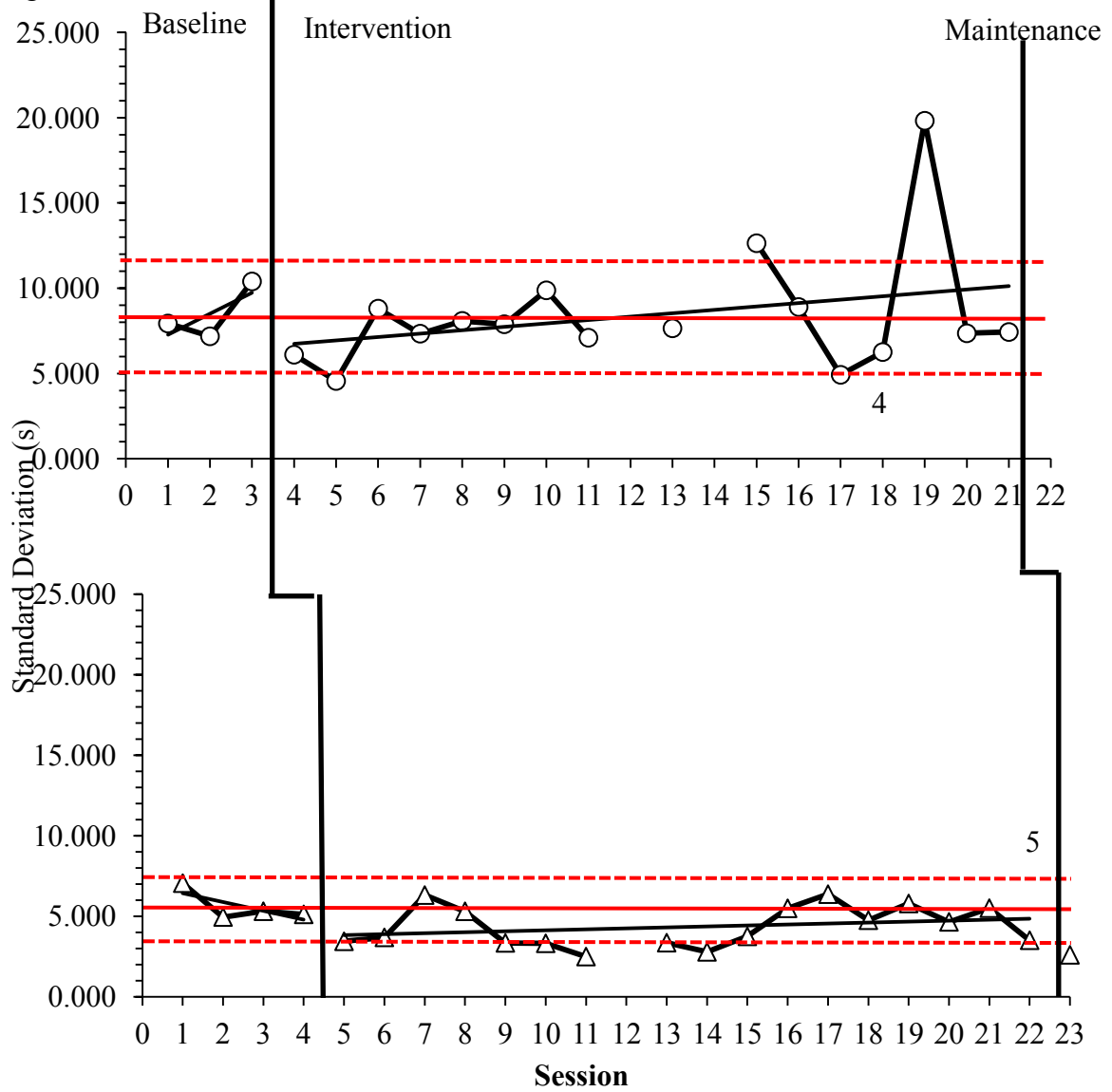


Figure 3.22

*Timed Up and Go Results*

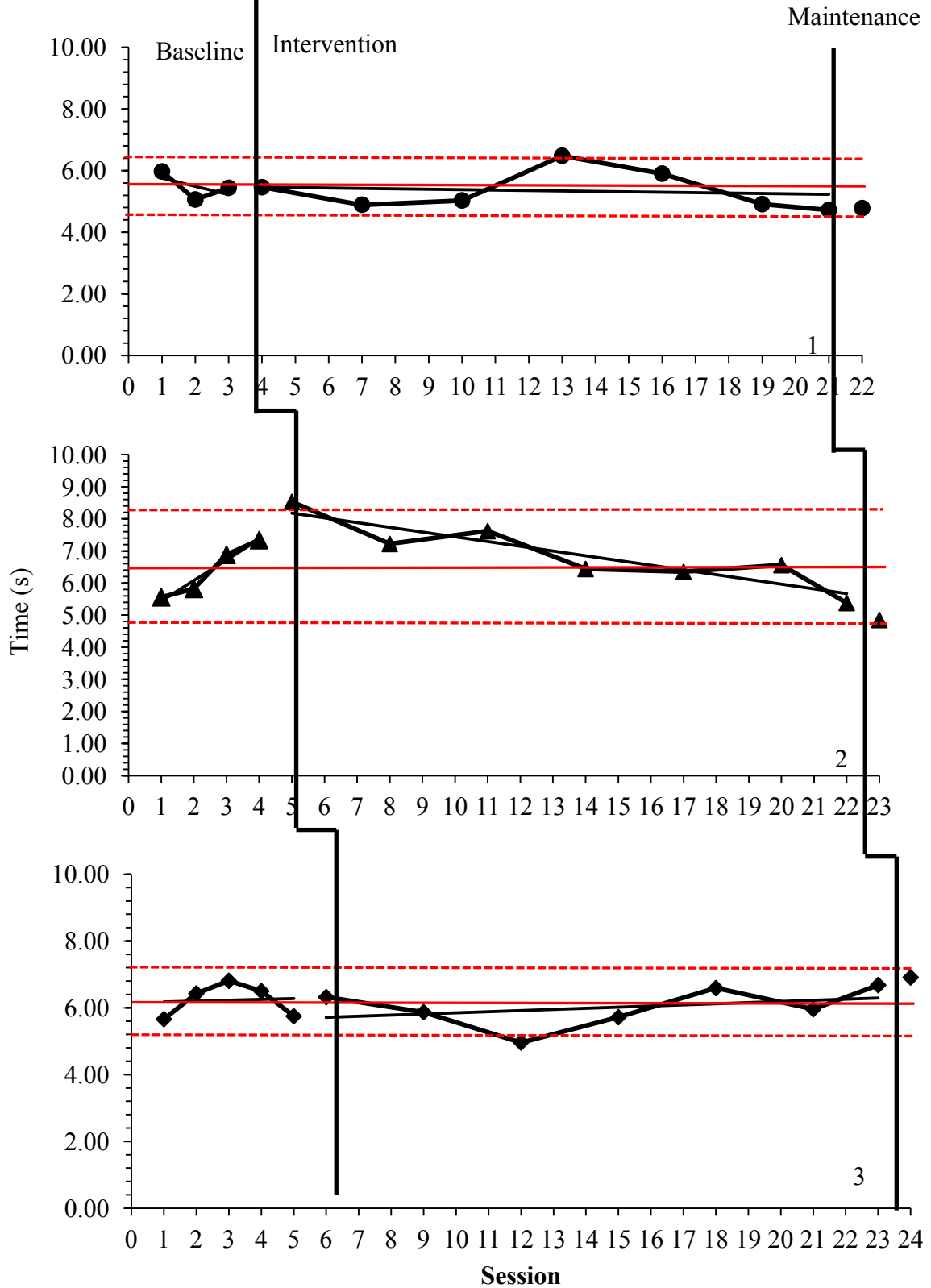


Figure 3.22 continued

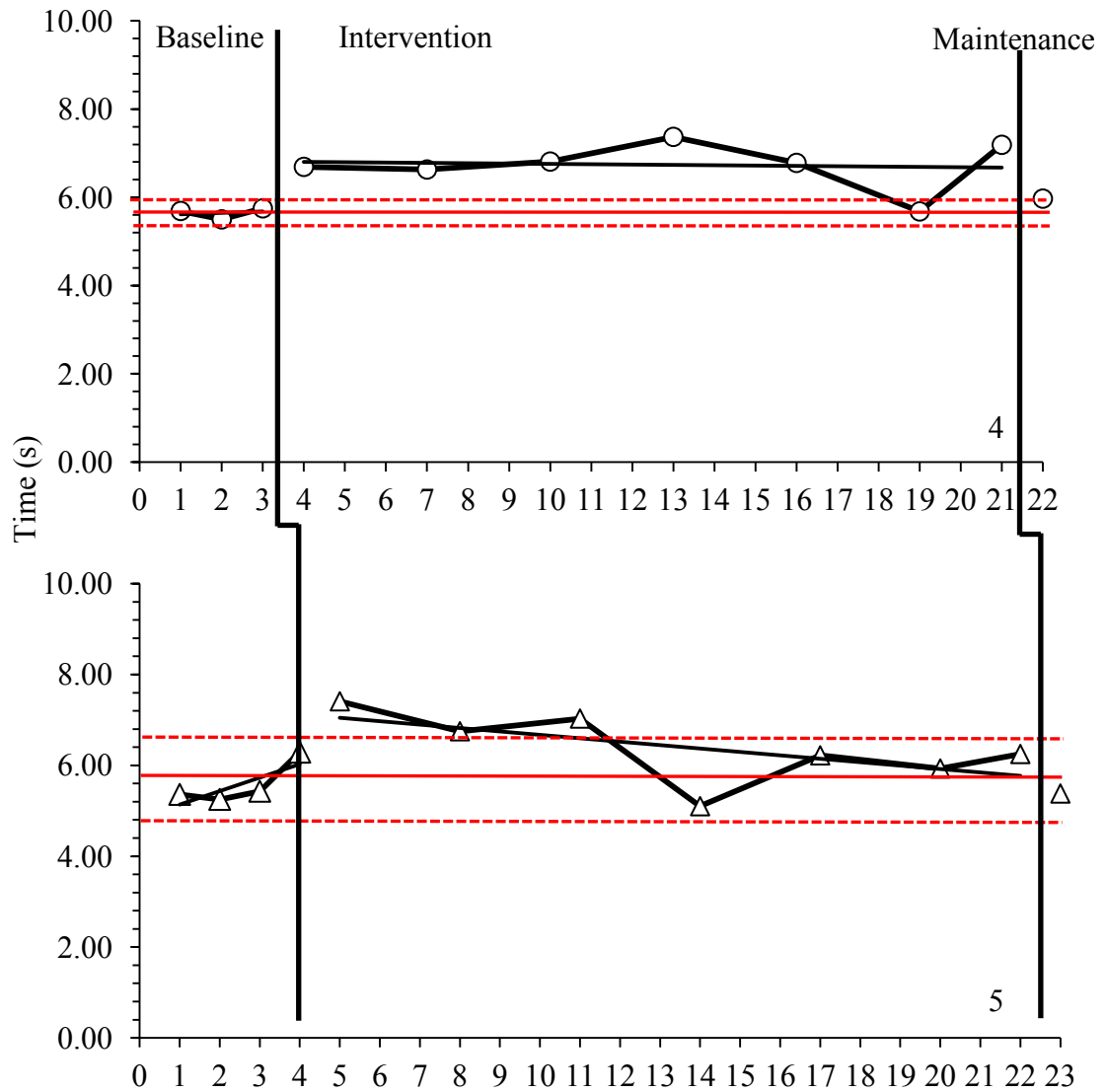


Figure 3.23

Gait Velocity Results

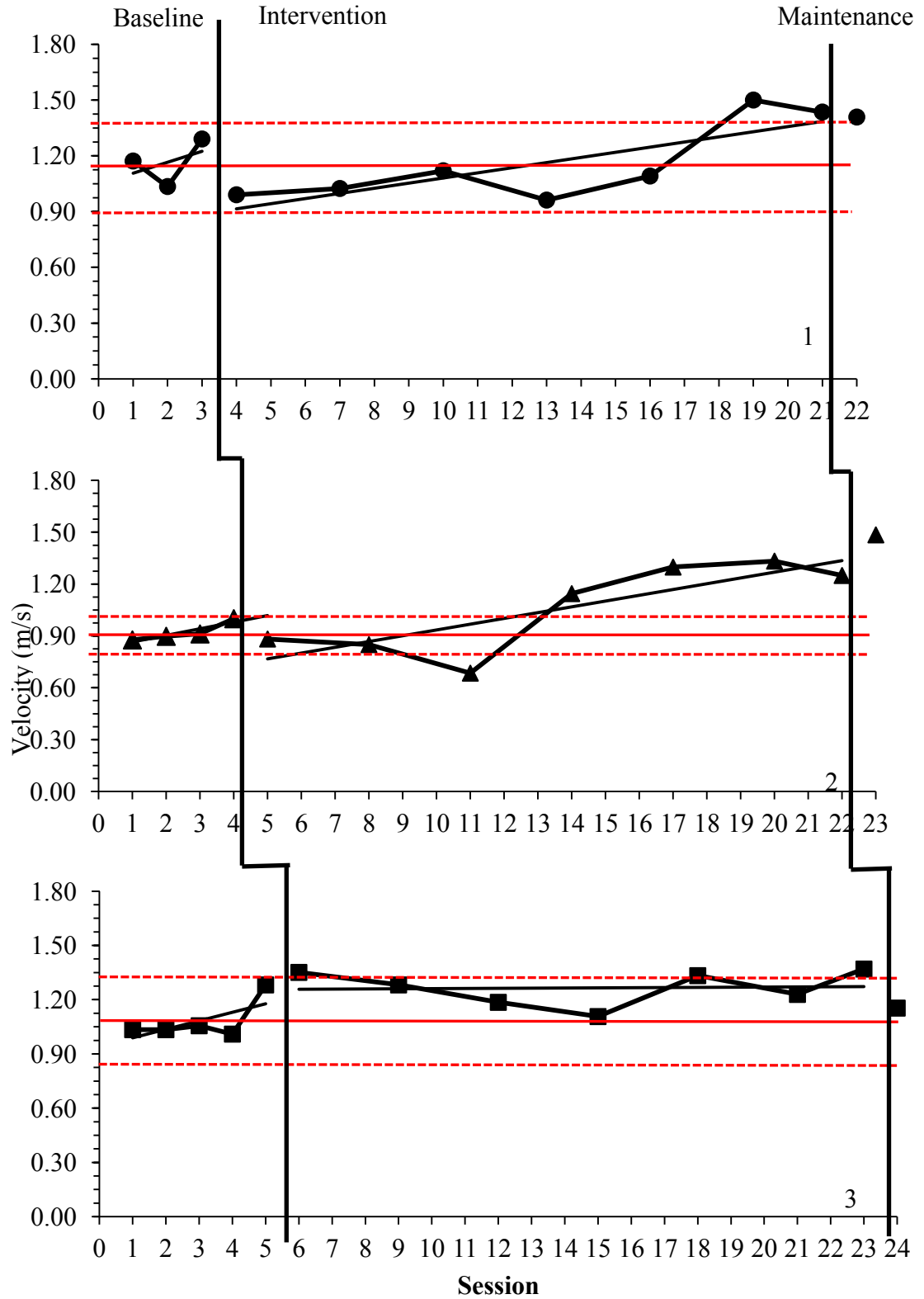


Figure 3.23 continued

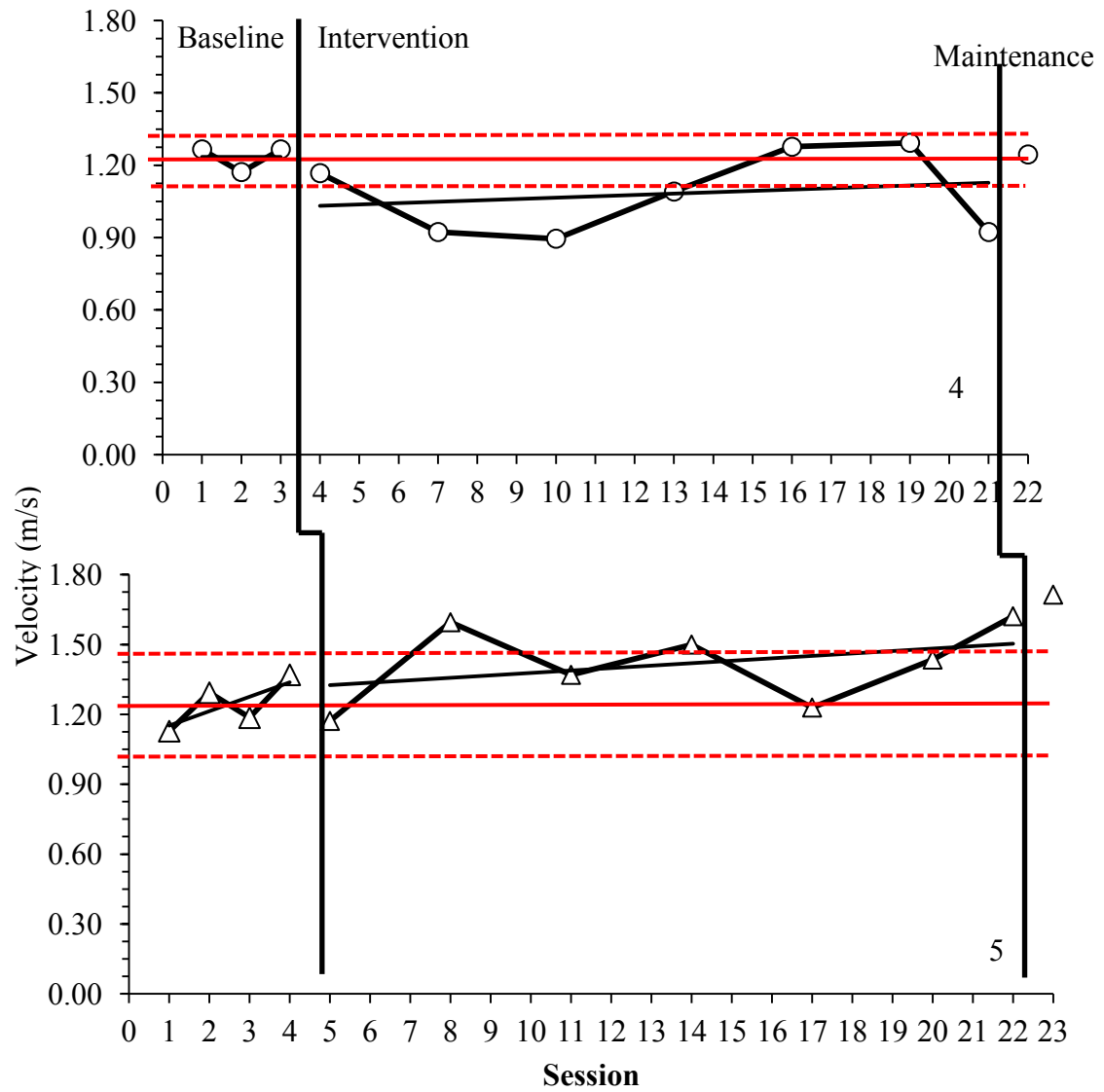


Figure 3.24

*Hip Abductor Strength Results*

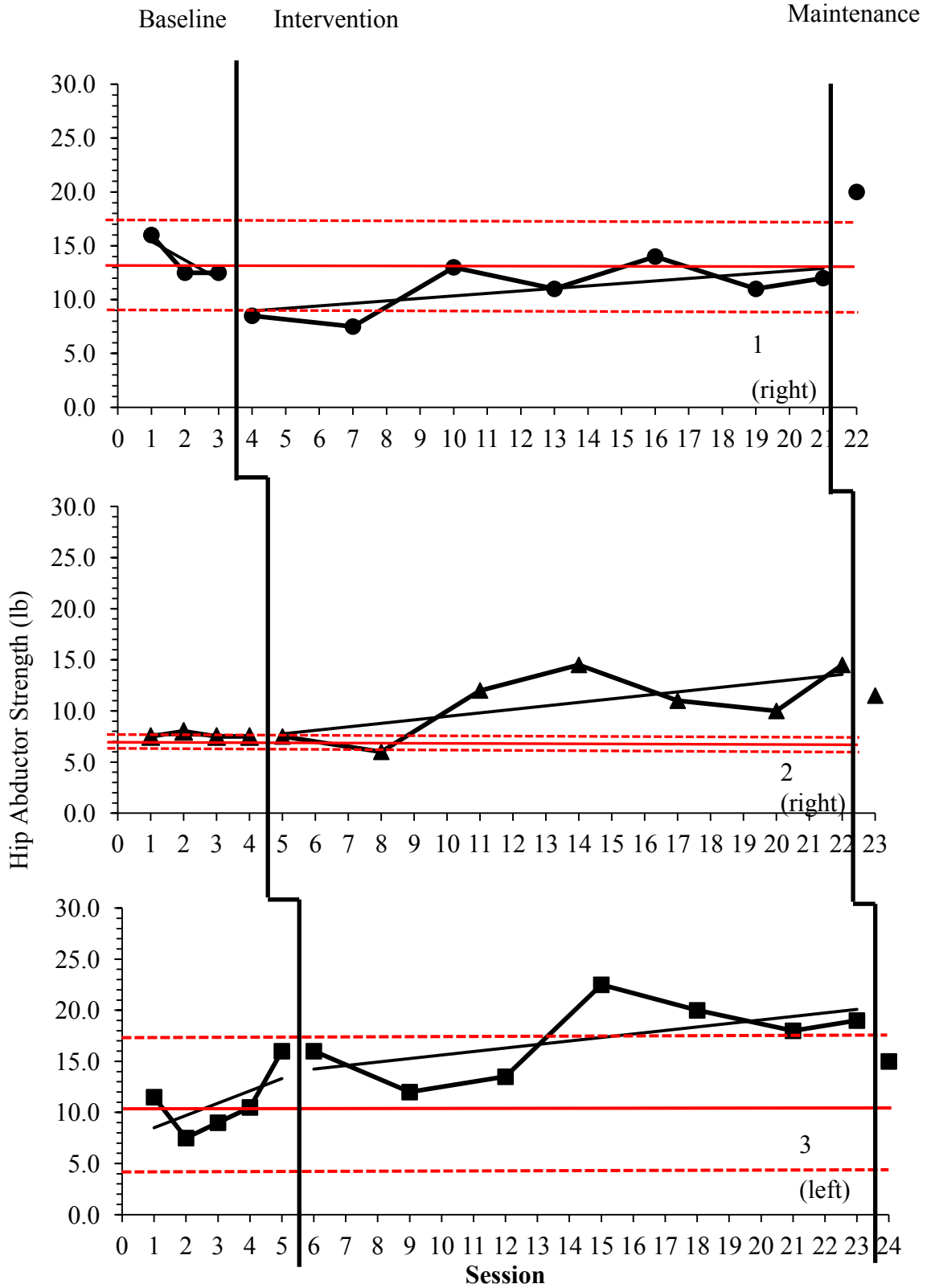


Figure 3.24 continued

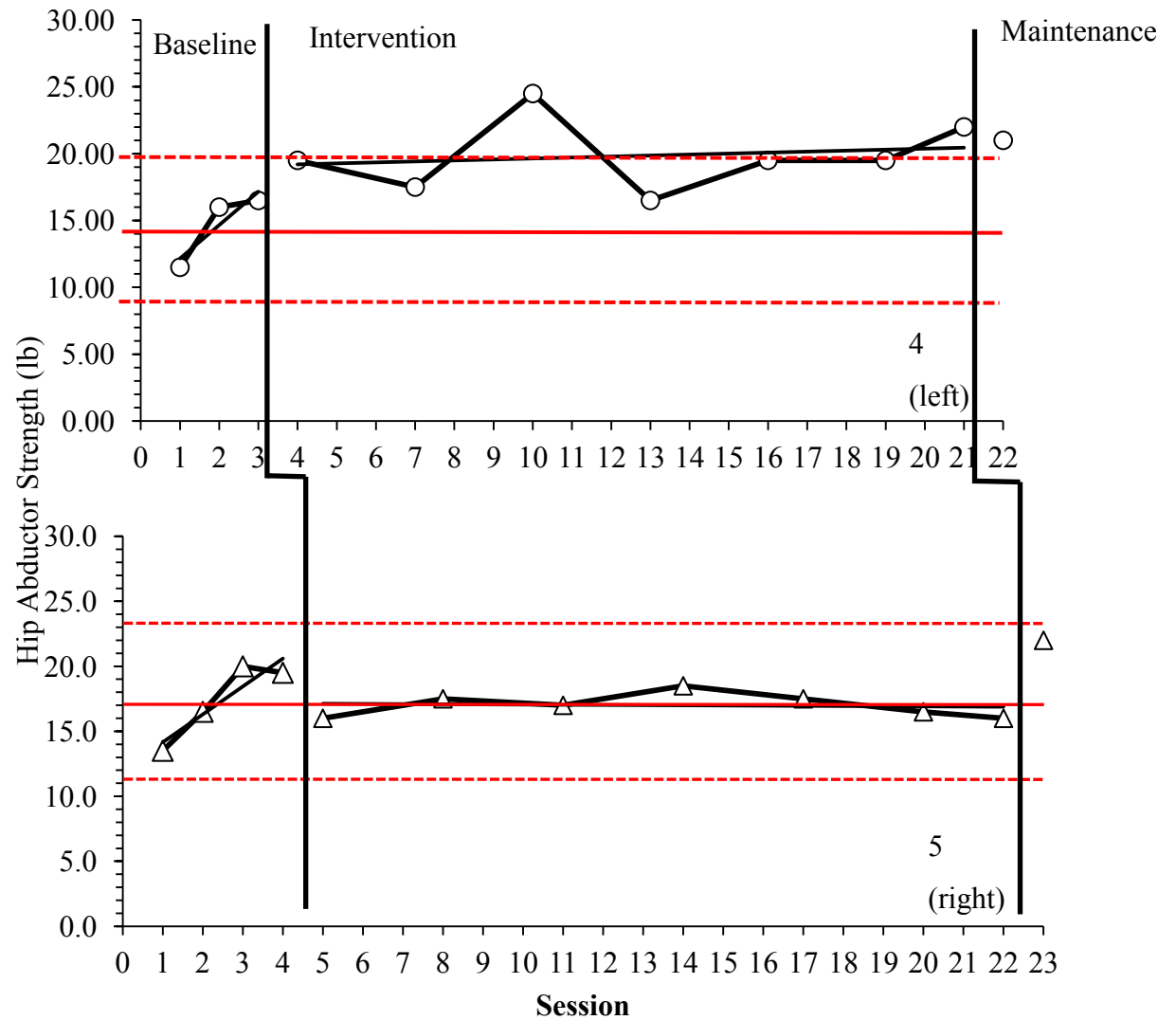




Figure 3.25

Activities Scale for Kids, performance version Results

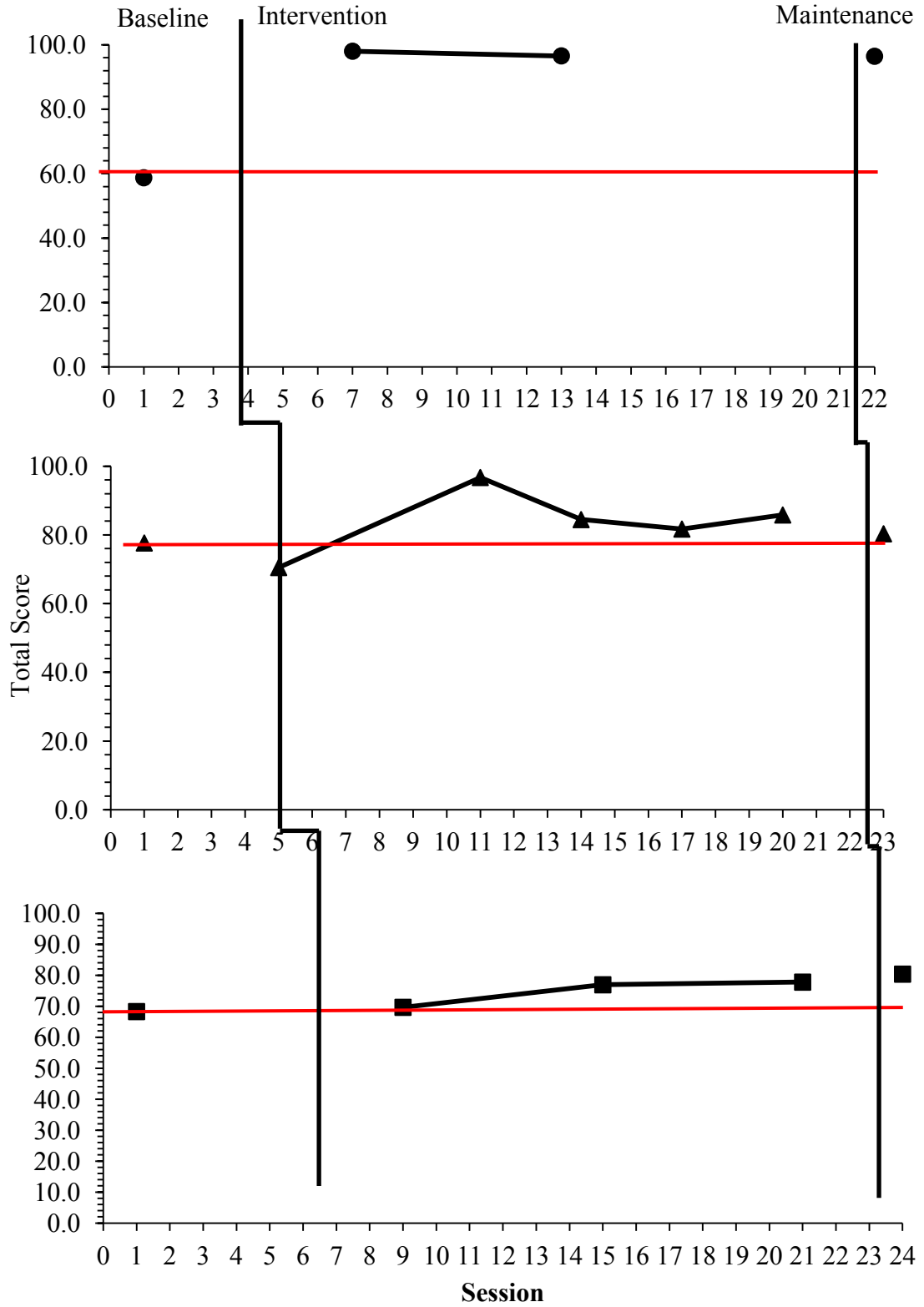


Figure 3.25 continued

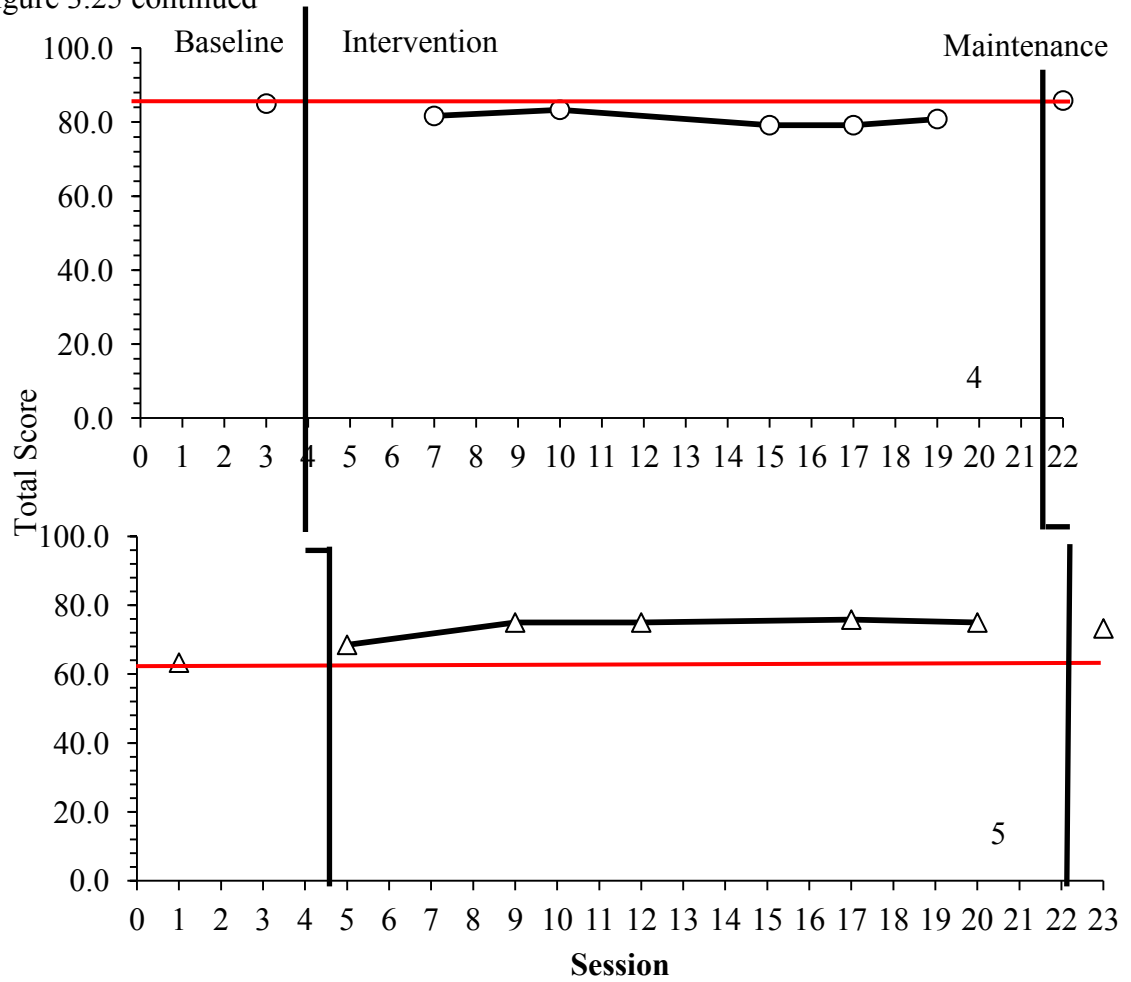


Figure 3.26

*Average Enjoyment and Difficulty Questionnaire Results*

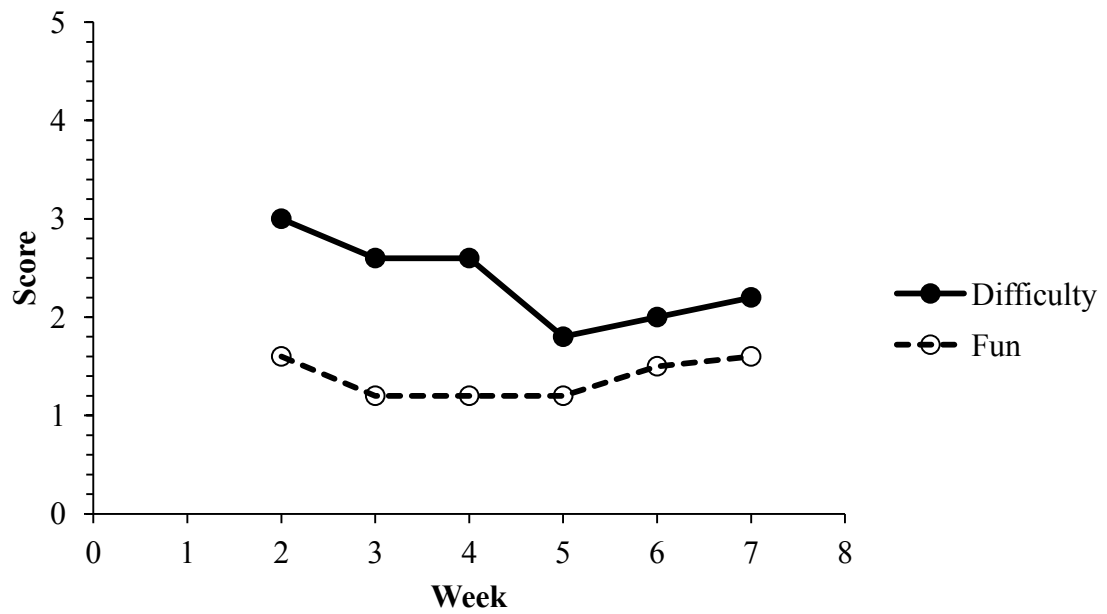


Figure 3.27

*Enjoyment and Difficulty Questionnaire Participant Results*

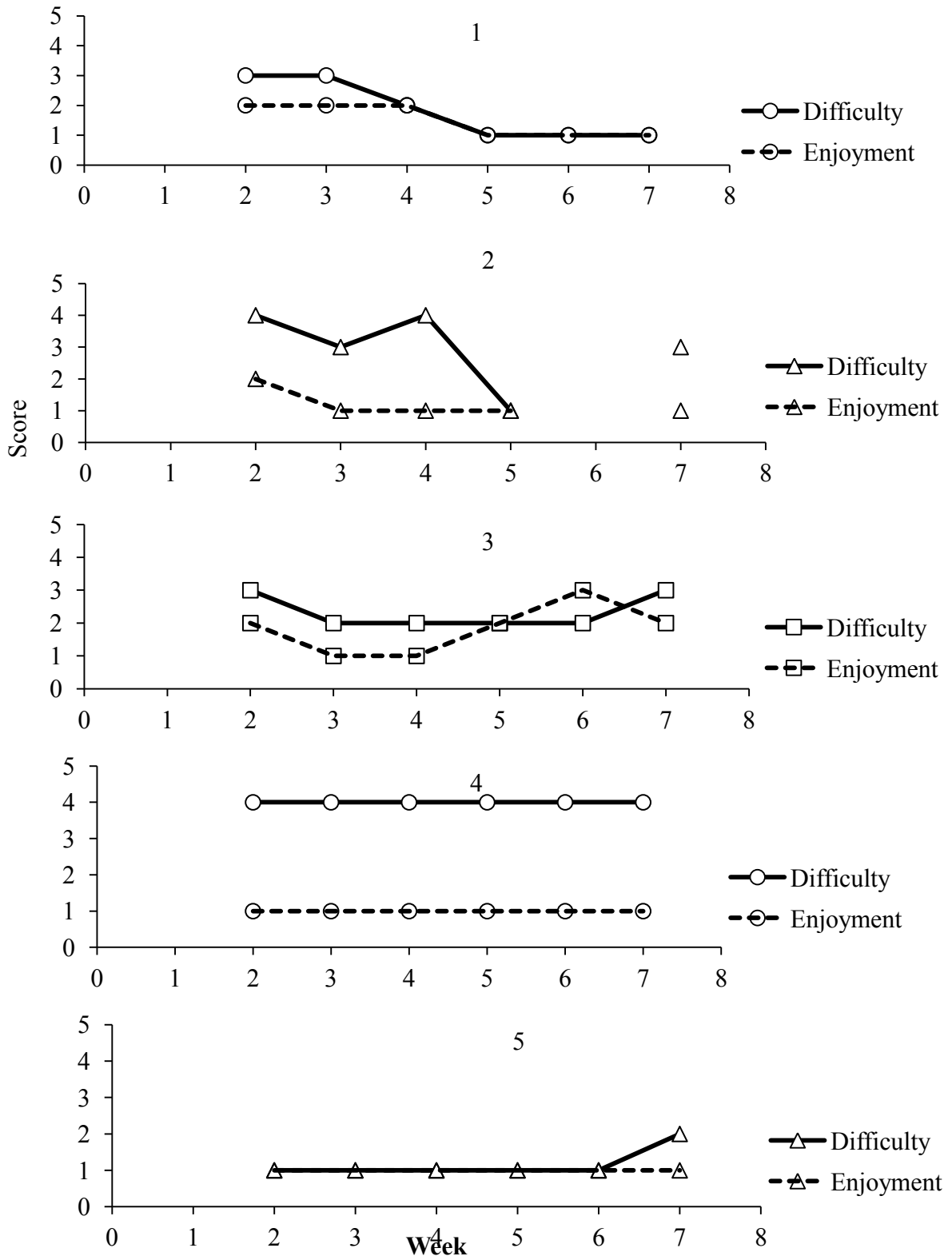


Figure 3.28

Average score for Soccer Heading

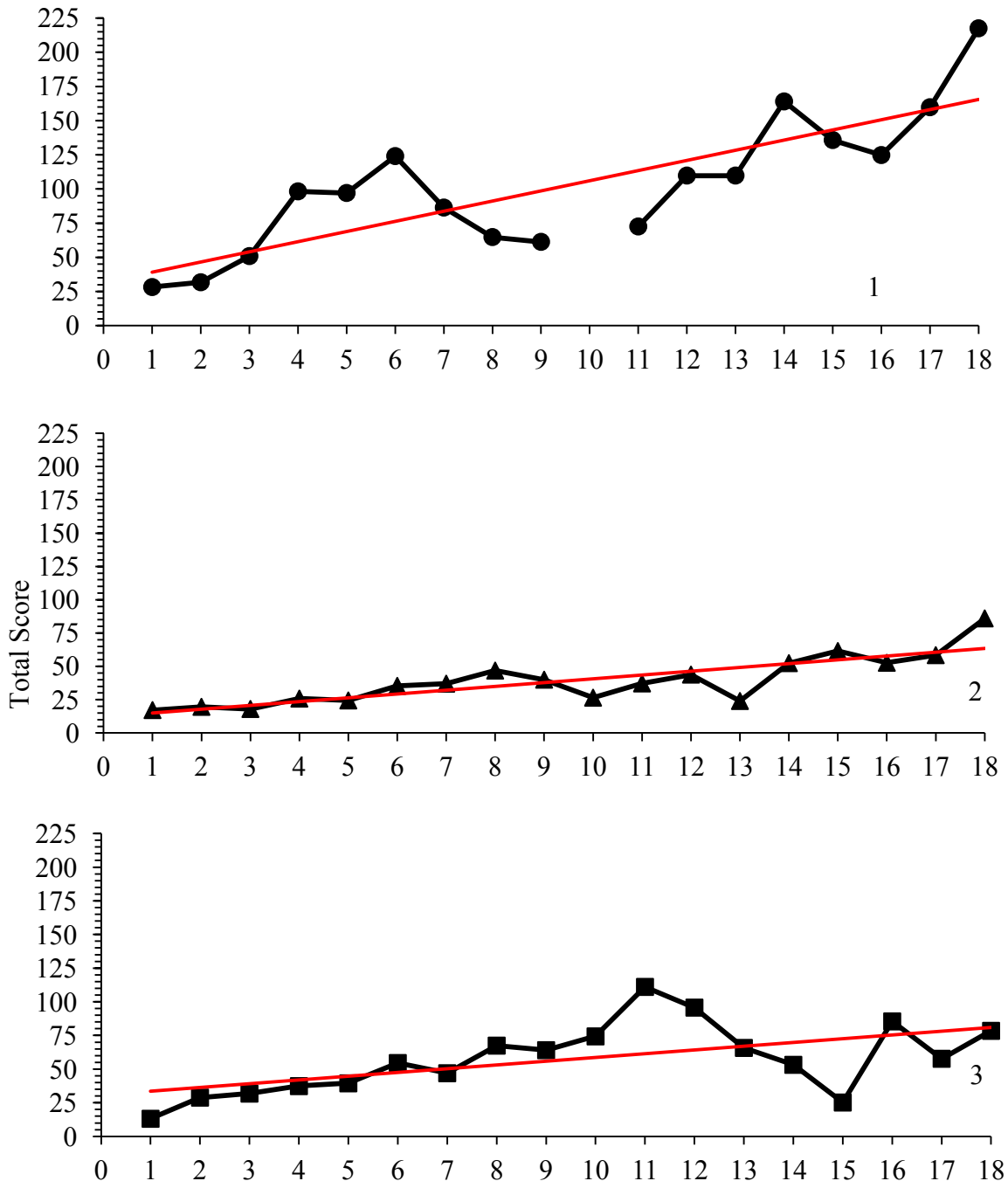


Figure 3.28 continued

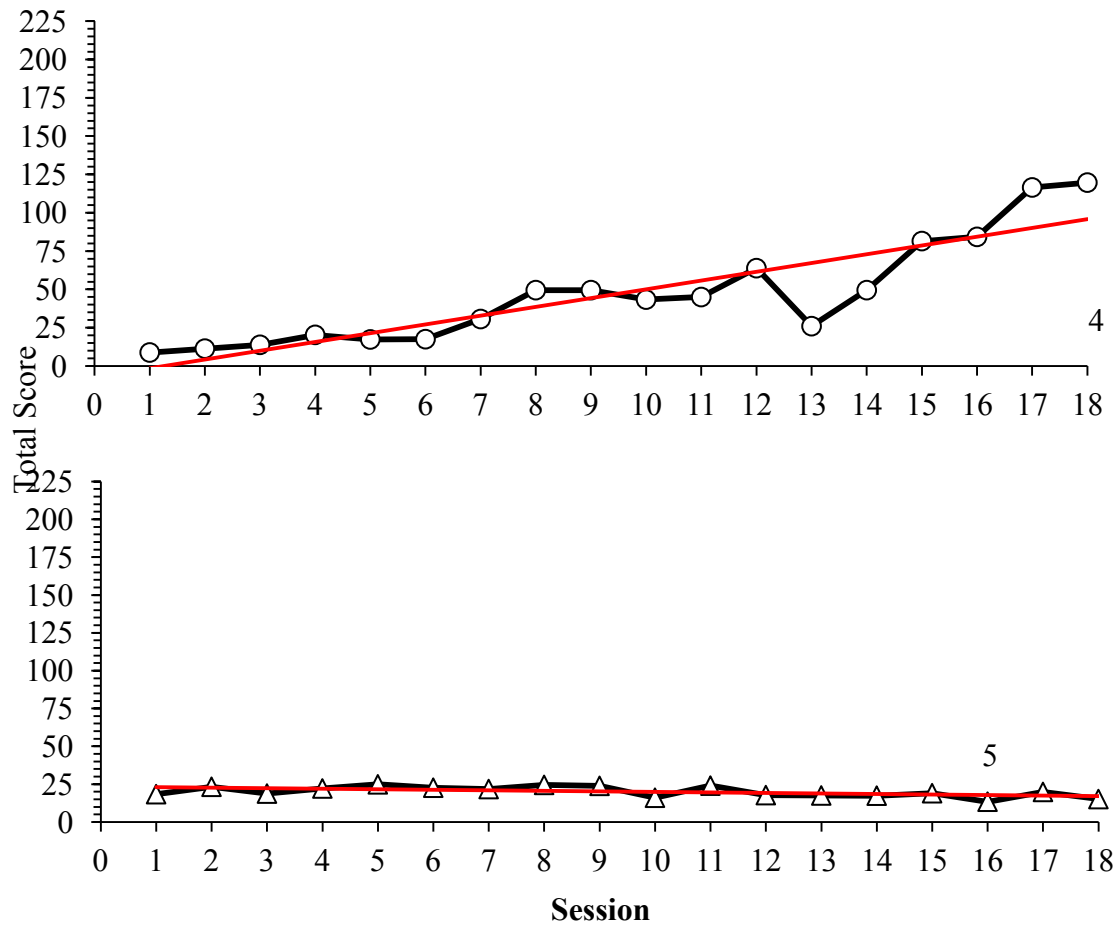


Figure 3.29

*Average score on the Balance Bubble*

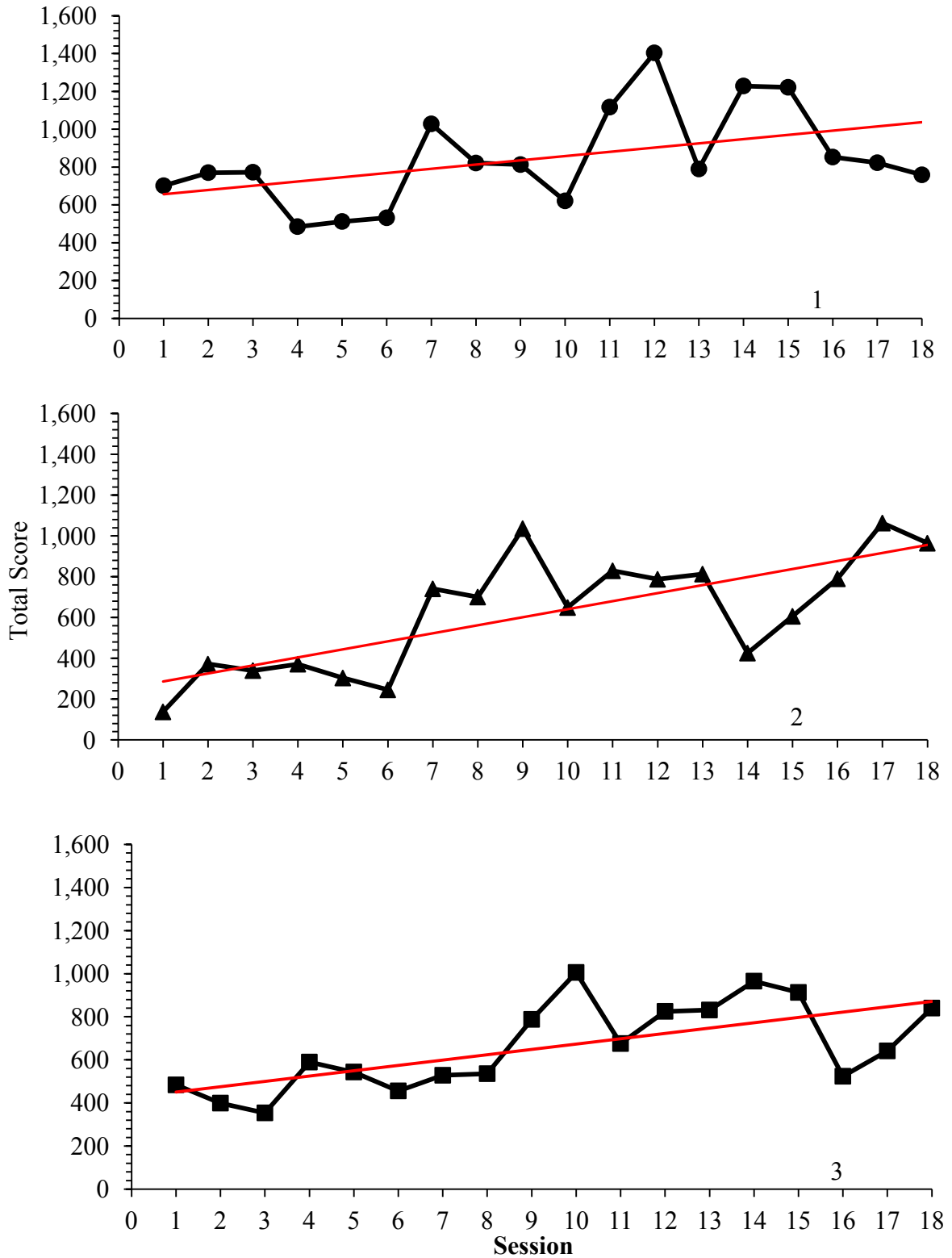


Figure 3.29 continued

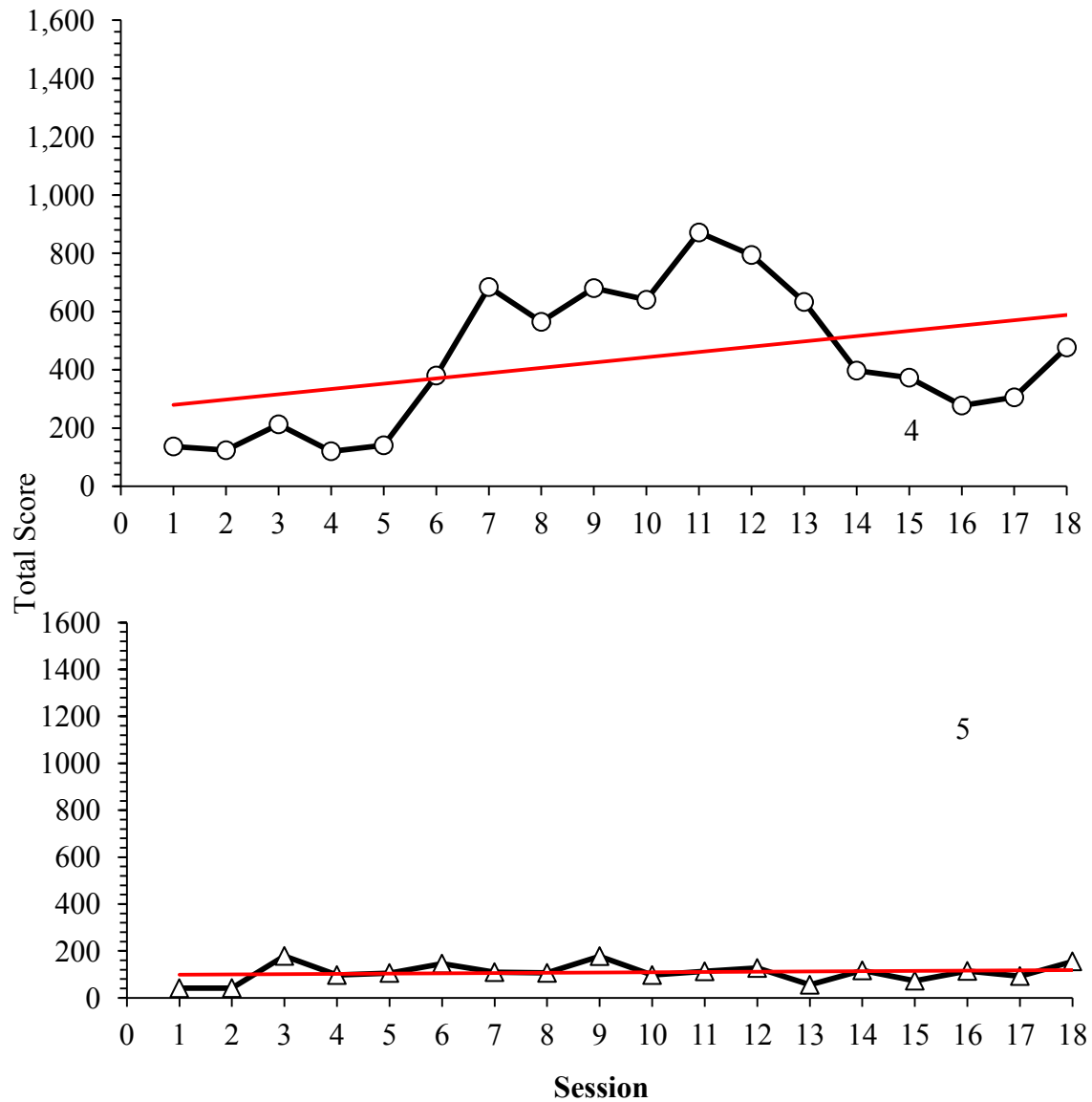




Figure 3.30

Average score on Penguin Slide

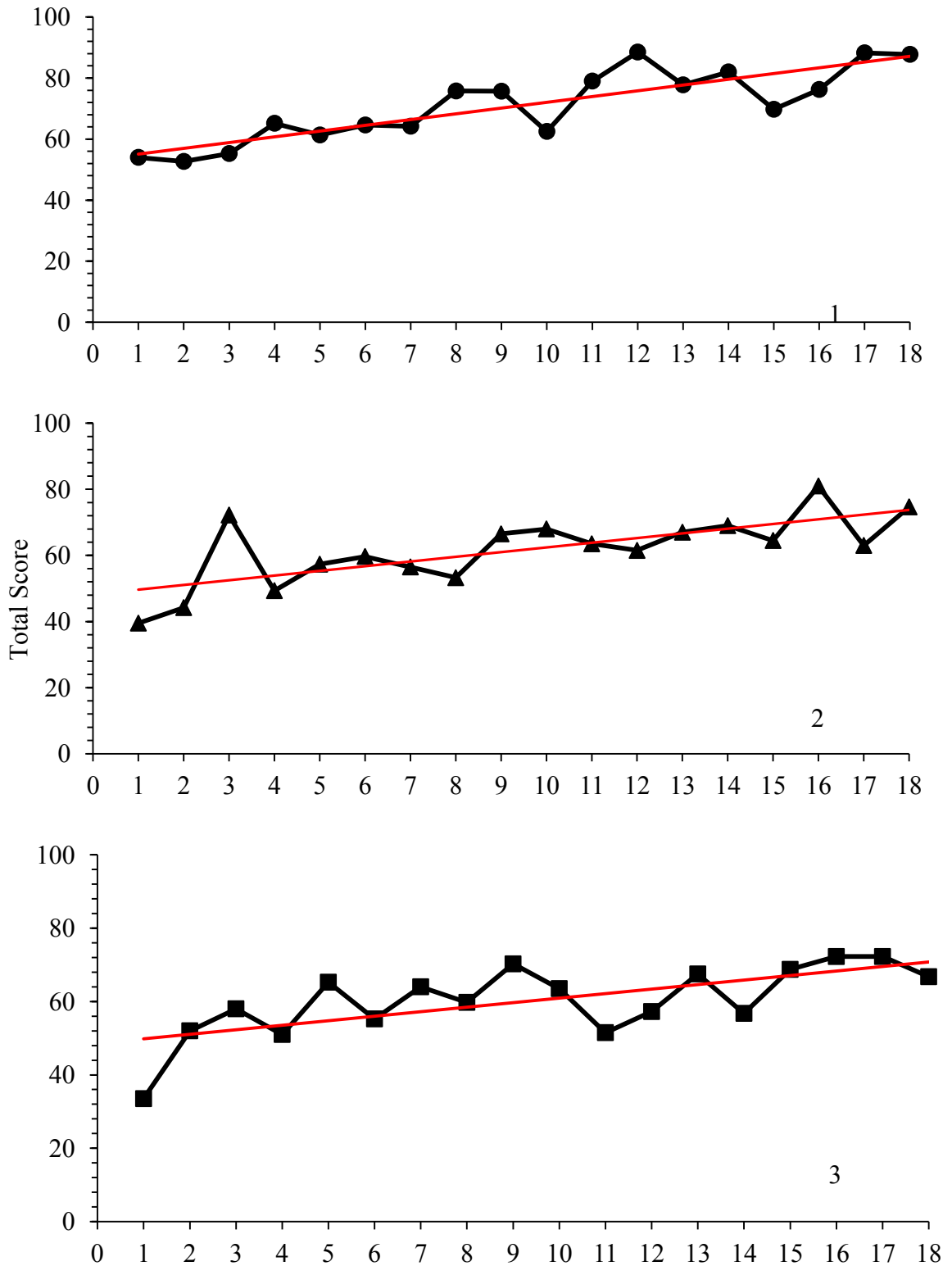


Figure 3.30 continued

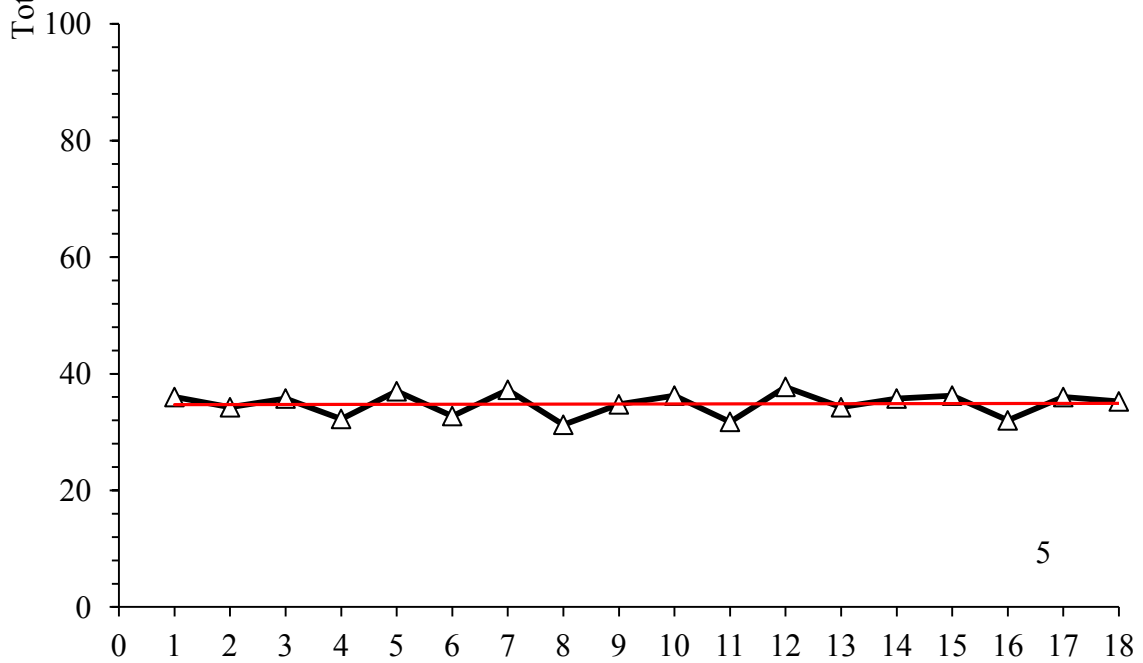
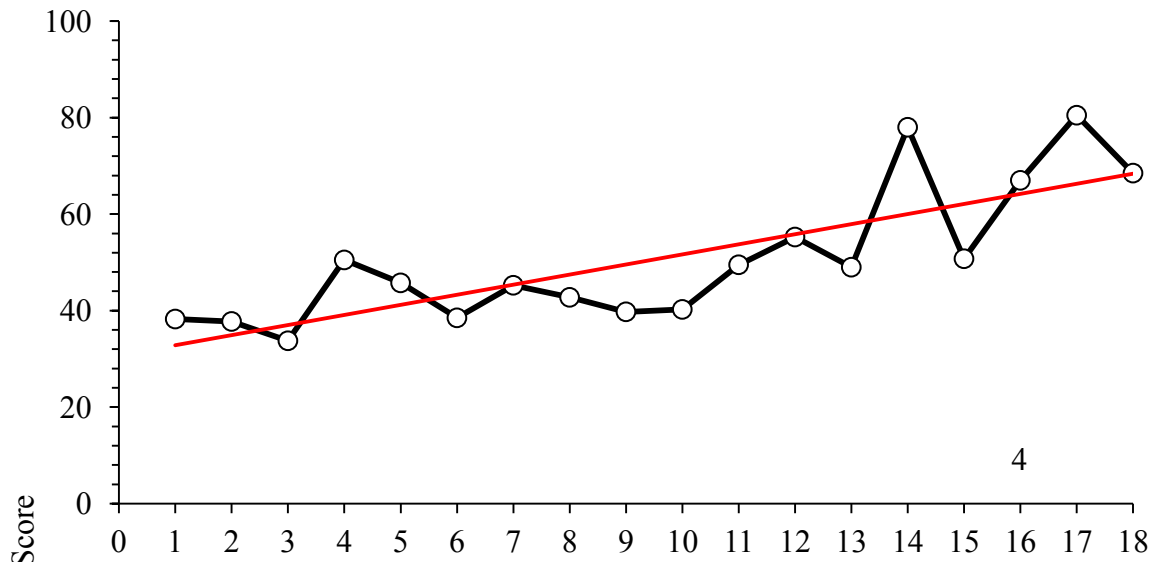


Figure 3.31

Average score on the Table Tilt game

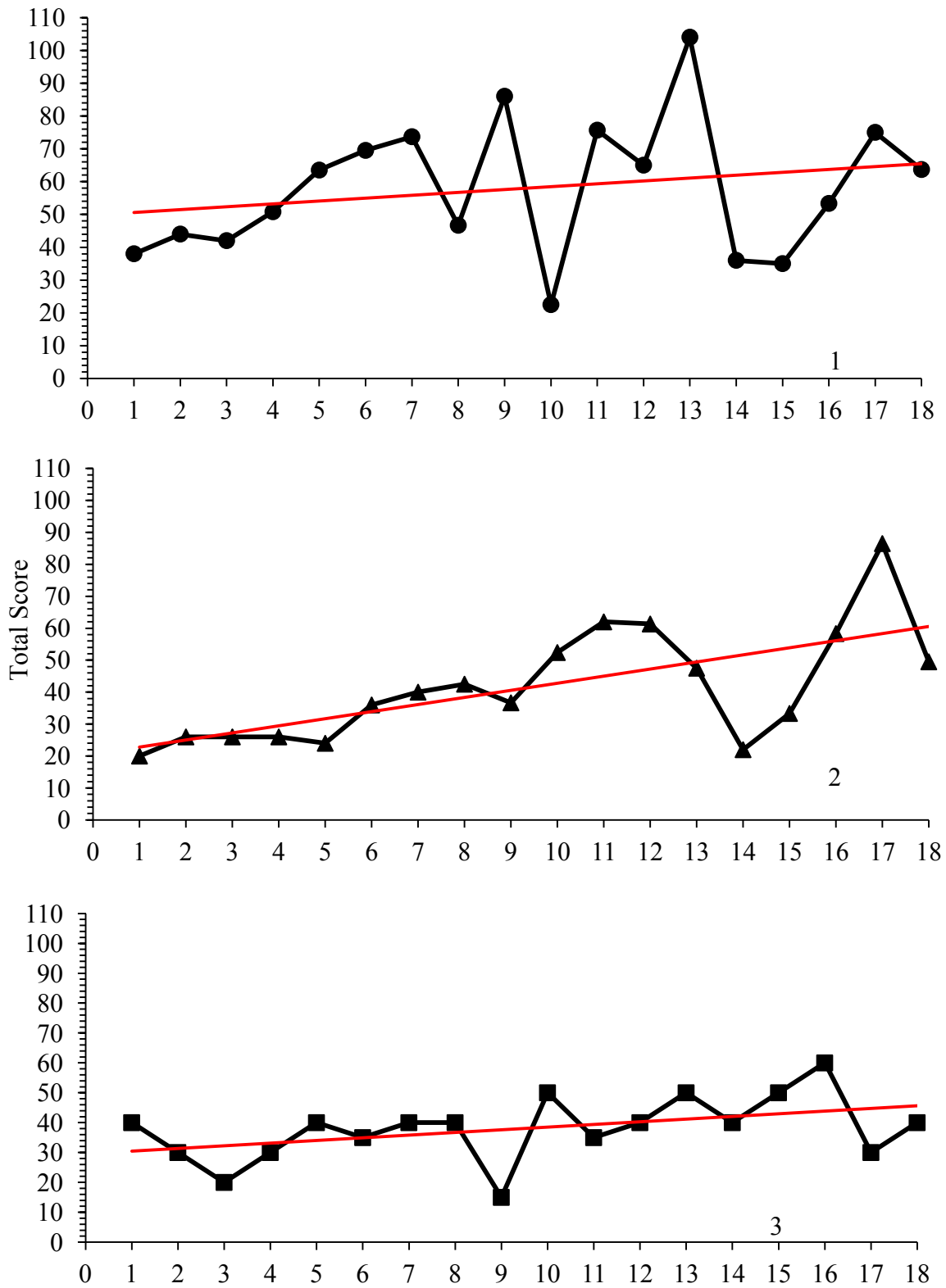
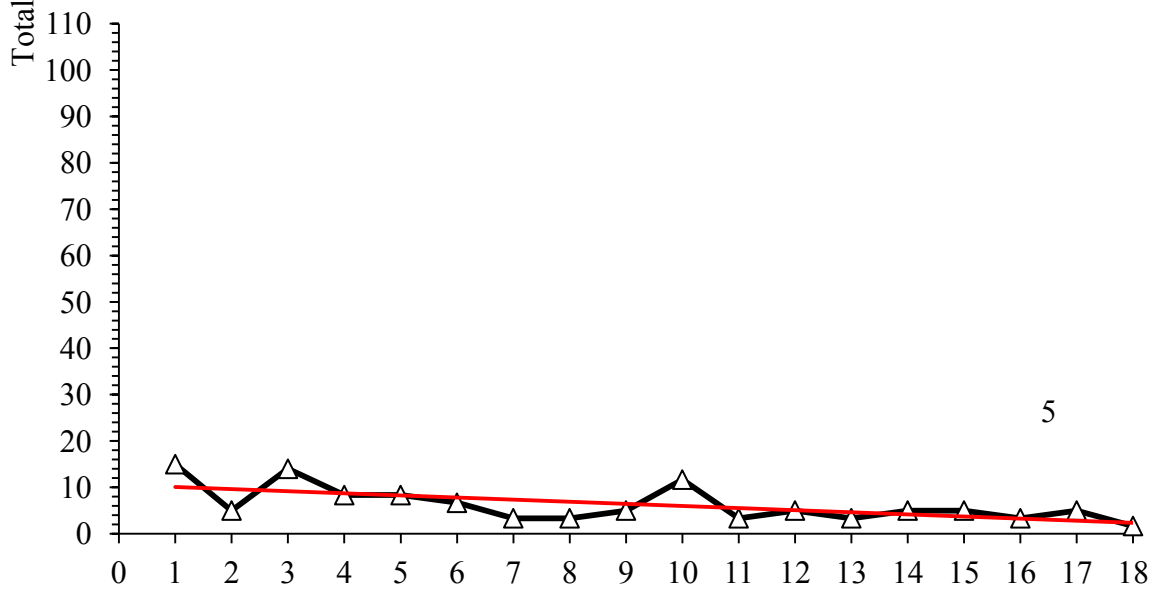
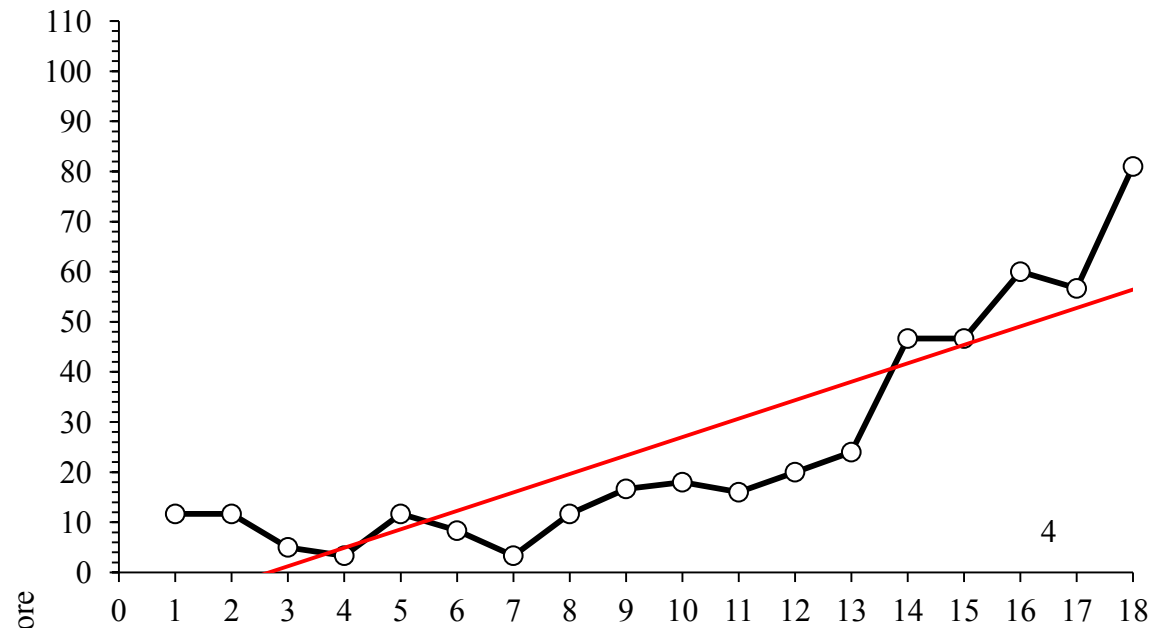


Figure 3.31 continued



## **Chapter Four: Effect of WiiFit™ Balance Training on the Balance and Function of Children with Developmental Disabilities**

### **Introduction**

For children with developmental disabilities (DD), including cerebral palsy (CP), Down syndrome (DS), and autism spectrum disorder (ASD), balance impairments are a common impairment of body structure and function (Chang et al., 2010; Chen & Woollacott, 2007; Gepner & Mestre, 2002; Girolami et al., 2011; Minshew, Sung, Jones, & Furman, 2004; Molloy et al., 2003; Nashner et al., 1983; Shumway-Cook & Woollacott, 1985a; Spano et al., 1999). The balance impairments of children with DD are in their anticipatory and reactive abilities, as well as postural sway during quiet stance (Ferdjallah et al., 2002; Fournier, Kimberg, et al., 2010; Galli et al., 2008; Kohen-Raz et al., 1992; Kokubun et al., 1997; Shumway-Cook & Woollacott, 1985a). For children with CP their balance abilities have been correlated to gait speeds, though this has not been demonstrated in other populations (Liao et al., 1997). Most children with DD have gait speeds that are slower than their typically developing (TD) peers (Liao et al., 1997). These slower gait speeds have been attributed to many different causes, including an impaired ability to weight shift and decreased strength in the lower extremities (Agiovlasitis, McCubbin, Yun, Mpitsos, & Pavol, 2009a; Black et al., 2007; Damiano et al., 1995; Eek & Beckung, 2008; Kubo & Ulrich, 2006b; Ross & Engsborg, 2007).

Children with DD may have many impairments of body structures, but also impairments in activities and participation. These children do not participate in the same types of activities as their TD peers (Imms et al., 2008), have more solitary play, engage more frequently with adults than their same age TD peers (Nadeau & Tessier, 2006; Richardson, 2002), and participate in less physical activities. The intensity of physical activity for children with DD is related to severity of their physical impairments (Imms et al., 2008; Majnemer et al., 2008). It is important that children with DD engage with their TD peers for the social and physical opportunities that it presents.

To foster this engagement many activities must be modified for children with DD. While most accommodations can be performed easily it often involves the assistance of an adult, which changes the nature of the play for children. Identification of common

activities that do not need to be modified, such as video games, allow children to play independent of an adult. The Nintendo Wii was utilized by Deutsch and colleagues (2008) as a training program for an adolescent with CP and a TD peer participated during some training. Improvements were found in body structures and functions, but it was also reported that the adolescent with CP imitated strategies of his TD peer and turn taking and encouragement occurred for both participants (Deutsch et al., 2008). The use of activity-based video games compared to traditional video games may allow increased opportunities for socialization and engagement between children who are TD and those with DD without the need for adult assistance.

The use of video games as therapeutic interventions has been growing in the literature for children with DD. The Nintendo Wii has been utilized for children with CP (Deutsch et al., 2008; Liu et al., 2009a; Nelson et al., 2010), DS (Berg et al., 2012; Wuang et al., 2011), and those with lower extremity amputations (Andrysek et al., 2012). Therapeutic outcome measures have included postural control measures, visual perceptual processing, graphomotor function, and measures of motor proficiency (Deutsch et al., 2008; Liu et al., 2009a; Wuang et al., 2011). These studies have investigated changes in body structure and function, but none have addressed if a therapeutic activity using a video game changes the activities or participation of a child with a DD. The purpose of this study was to examine the effects of a video game based multi-directional balance training intervention on the balance, gait velocity, strength, and activities of children with DD.

## **Methods**

### **Research Design**

This study was a single subject, non-concurrent, multiple baseline design across participants and variables. The format for the study included baseline and intervention phases and maintenance follow-up.

### **Approval, Consent & Assent**

Approval for this study was obtained from the University of Kentucky Medical Institutional Review Board with a full review from modification of the pilot study

(Chapter 3). Informed consent was obtained from the parent or guardian prior to beginning the study and child assent was also obtained. The forms for informed consent and child assent are provided in Appendix A.

### **Participants**

Participants were recruited as a convenience sample from local therapy agencies and school districts throughout Kentucky. Fliers were distributed to therapists who were asked to pass along to potential participants. Participants were compensated for each week of participation in the study, for a maximum of \$80 and were entered in a drawing to win their own Wii™ and WiiFit™.

#### **Inclusion criteria.**

Participants had to have a diagnosis of hemiplegia or diplegia CP, DS or other DD and were between the ages of 5 and 10 years at the beginning of the study. Participation of children with CP required a classification on the GMFCS at level I, II or III (Palisano et al., 1997; Palisano et al., 2008). The participants had to be able to stand without support for 3 minutes and follow two-step directions. Participants also had to be free from an ear infection in the past 6 weeks (Casselbrant et al., 2000), have no known hearing impairment per parent report, and normal or corrected to normal vision. Participants were not to have undergone spinal or lower extremity surgery in the past 3 months, as this is known to significantly affect gait abilities (Gage, 1990). The participant must be able to tolerate 30 minutes of focused activity.

#### **Exclusion criteria.**

Participants were excluded if they had a diagnosis of quadriplegia, athetoid or hypotonia CP. Children with DD unable to participate in regular physical education classes or those with physician notes limiting their physical activity were also excluded from the study. Those with uncontrolled seizure disorders were excluded, as were those who have had a history of an ear infection not healing in 3 months time, or those not meeting the inclusion criteria.

### **Participant demographics.**

Six children with disabilities enrolled in this study. The disabilities included: CP, DS (2 participants) sensory processing disorder, developmental delay and ASD (Table 4.1). Participant B dropped out of the study at the end of the baseline phase prior to beginning intervention due to family constraints, and participant E stopped participating during the 4<sup>th</sup> week of intervention due to a combination of lack of progress and family constraints. Thus four children completed the entire study.

### **Assessment Tools and Outcome Measures**

Reliability and validity of the assessment tools and outcome measures are reported in Chapter 2. Administrations of the assessment tools are described in Chapter 3, except for single limb stance time (SLST). All assessment tools were administered at the participants' homes, in barefeet and without assistive devices.

### **Measures of body structure and function.**

The balance measures for this study included: weight-bearing symmetry (WBS), center of pressure (COP) area and velocity with the eyes open (EO) and eyes closed (EC), time to boundary (TTB) mean minima and standard deviation (SD) with EO and EC for the anterior-posterior (AP) and medial-lateral (ML) directions, and SLST. The timed up and go was not included in this study due to poor results from pilot testing. WBS and COP/TTB measures were administered as described in the previous chapter. Administration of SLST is described below.

### ***Single limb stance time.***

SLST was assessed with the limb of choice of the participant at the first baseline assessment and kept consistent throughout the study. The participant was barefoot and asked to stand on the preferred limb with hands on hips, flex the opposite limb to 90° of knee flexion with the EO (Figure 4.1). Timing began immediately when the knee reached 90° of flexion and concluded when the knee fell below 45° of flexion, the foot of the supporting limb moved from the starting position, the hands came off the hips, or if the subject maintained SLST for 30 seconds with the EO (Atwater et al., 1990; Liao, Mao, &



Hwang, 2001). Three trials were performed and the most complete (longest) trial was used for analysis.

Other measures of body structure and function included in this study were gait velocity (GV) and hip abductor strength (HAS). These were administered as discussed in Chapter 3.

### **Measures of activity limitations and participation restriction.**

Participants were administered the Activities Scale for Kids, performance version (ASKp, Appendix B) as described in Chapter 3. The Enjoyment and Difficulty Questionnaire (EDQ, Appendix C) was administered at every intervention session.

### **Procedures**

The following section describes the procedures for study, beginning with reliability, testing, and intervention procedures, and concluding with an updated description of the phases (baseline, intervention and maintenance).

#### **Reliability.**

##### ***Inter-rater reliability.***

Inter-rater reliability was tested throughout the study between the primary researcher and one licensed physical therapist (PT) and one licensed occupational therapist (OT). Three of the six participants were randomly assigned to be part of reliability testing. The OT assessed two of the subjects, while the PT assessed one subject. Inter-rater reliability was assessed for the SLST, GV and HAS during all three phases. Specifically, 1 test occurred at baseline, 2 during the intervention and 1 during maintenance for all three participants. The primary researcher administered each measure first and the PT or OT then administered each measure.

Inter-rater reliability were not performed for WBS, COP, TTB, ASKp and EDQ. The WBS, COP and TTB reliability were assessed through procedural reliability, discussed in the following section.

### ***Procedural reliability.***

Procedural reliability was performed for WBS, COP, and HAS outcome measures as described in Chapter 3. Reliability during each session was addressed using checklists (Appendices F-I). The primary researcher used the modified checklists during each session and an outside observer was present at three intervention sessions for each of the four participants. The outside observer also used the checklists to ensure that procedures were followed.

### **Testing procedures.**

The participants self-selected the order of administration of the measures, and wore a safety belt during GV, SLST, COP/TTB and WBS. During the baseline phase HAS, GV, SLST, COP/TTB and WBS were administered one time at every session (Figure 4.2). The ASKp was administered once during the baseline phase, and the EDQ was not administered. During the intervention phase COP/TTB, WBS and EDQ were administered at all 18 sessions (Figure 4.3). The HAS, GV, and SLST were administered one time per week during the intervention phase and on the final day of the intervention session, for a total of seven times during the intervention phase. The ASKp was administered once per week during the intervention phase, for a total of six administrations. At the maintenance phase all outcome measures, except the EDQ, were administered one time.

### **Intervention procedures.**

The intervention procedures are described in detail in Chapter 3. Changes made to the intervention include the addition of two extra balance games: Ski Slalom (SK) and Snowboard Slalom (SN). Complete descriptions of SK and SN are in Appendix D and screen shots of the additional games are in Figures 4.4. The SK game involved primarily lateral weight shifting, while the SN requires multi-directional movements.

The intervention occurred at home under the direct supervision of a licensed PT 3 times per week for 30 minutes for 6 weeks, as in the pilot study. To ensure that equal time was played on games that focused on primarily lateral (15 minutes) and multi-directional weight shifting (15 minutes) a predetermined number of repetitions was required. Soccer heading (SH) was played 5 times, balance bubble (BB) 5 times, penguin

slide (PS) 3 times, table tilt (TT) 5 times, SK 4 times, and SN 5 times all at the beginner difficulty setting. As the participant progressed through the different difficulty settings, the maximum number of trials of each game changed accordingly, for instance when the participant progressed to the advanced setting on SH the maximum number of times played decreased to three. Progression through the difficulty settings was determined in the same manner as the pilot study: by the therapist and participant request. At a minimum, the participant had to successfully complete a game repeatedly over 1 week to the 2 star rating (see Appendix E) before they would be progressed to the next difficulty setting.

### **Description of phases.**

#### ***Baseline phase (Week 1).***

Baseline lengths were pre-determined to last a minimum of 5 sessions and a maximum of 10 sessions. Five sessions is the minimum baseline length based on recommendations from the American Academy of Cerebral Palsy and Developmental Medicine (Romeiser Logan et al., 2008). A maximum of 10 sessions was selected because more than 10 might not be clinically feasible.

On the first day of baseline testing measures (WBS, COP/TTB, SLST, GV, HAS) were administered in an order self-selected by the participant. The ASKp was left with the participant to complete following the first session and picked up by the end of the baseline phase. Three participants did not own a Wii™, so they created a personal avatar on the first day of baseline testing for use during WBS testing and balance training.

#### ***Intervention phase (Weeks 2-7).***

At the beginning of each new intervention week the participants were administered SLST, GV, and HAS in a self-selected order, while the ASKp was left for them to complete. Each intervention session began with administering the following tests: COP/TTB and WBS. Directly following the administration of these tests the balance-training intervention began (Figure 4.3). At the end of each intervention session the EDQ was administered. On the last day of the intervention all participants were administered all measures (HAS, GV, SLST, COP/TTB, WBS, ASKp, and EDQ).

### ***Maintenance (Week 8).***

At one-month following the last intervention session testing was repeated. All measures (HAS, GV, SLST, COP, TTB, WBS, ASKp) were administered in one session.

### **Data Analysis**

#### **Visual analysis.**

All data were graphed using Microsoft Excel 2011 for Macintosh. Data from each subject and measure were analyzed using visual analysis, beginning with the baseline phase and establishing the mean, level, and trend, visually assessing variability, and then computing two SDs around the mean. Mean, linear trendlines, and the two SDs were calculated with Microsoft Excel 2011 for Macintosh.

Visual analysis continued with analysis of the intervention data for all of the measures. Data was again analyzed for mean, level, and trend. Intervention data was compared to baseline phase data using the two-SD band method. A significant change in behavior was defined *a priori* as three consecutive data points in the intervention phase that were outside of the two SD band lines from baseline phase (Kazdin, 1982; Portney & Watkins, 2008a). The two SD band assessment was not conducted for ASKp or EDQ. WBS data were analyzed by counting the number of data points that fell within the range of 48-52%. Three consecutive points within the range was considered a significant change in behavior.

#### **Statistical analysis.**

Data analysis were also conducted statistically using Statistical Package for the Social Sciences (SPSS, Inc. Chicago, IL) version 19.0 for Macintosh and Microsoft Excel 2011 for Macintosh. The *C* statistic was used to statistically analyze the trends in the data between the baseline and intervention phases, for all measures except the ASKp. Data were also analyzed statistically for effect size for all measures that demonstrated significant changes either through the two SD band method or the *C* statistic. As in the previous chapter the improvement rate difference (IRD) was selected because it allows for a baseline to intervention comparison and could be averaged across participants in a multiple-baseline design (Parker & Hagan-Burke, 2007; Parker et al., 2009). The IRD

correlates with other traditional effect size measures including Pearson's R and Kruskal-Wallis square-root of W, but has fewer statistical assumptions than these traditional measures (Parker et al., 2009). An interpretation guideline for the IRD is,  $IRD \leq 0.50$  is small, between 0.50 and 0.70 is moderate and  $> 0.70$  is large (Parker et al., 2009). The IRD was calculated as presented in the previous chapter.

### ***Reliability analysis.***

Reliability data were analyzed using the standard error of measure as discussed in the previous chapter.

## **Results**

### **Intervention Summary**

The intervention phase was scheduled to last 30 minutes, but varied with each subject (Table 4.2). The overall mean of time spent on the multi-directional balance-training program for all participants was  $27 \pm 4$  minutes. All participants began the program at the beginner settings for the games. In contrast to the participants of the pilot study, fewer participants progressed to the advanced levels of the training program. The average number of rest breaks and requests to change activities (Figure 4.5) was not greater than one for any session.

### **Reliability**

The inter-rater reliability results are presented in Table 4.3. The r-values calculated were high for all participants for SLST and GV. An r-value and SEM for SLST were unable to be calculated for participant A because his scores did not vary between raters or sessions. The HAS r-values were high for two participants, but not participant F.

### **Balance**

#### **Weight bearing symmetry.**

Figure 4.6 and Table 4.4 presents the results from WBS for 5 participants. WBS was hypothesized to stabilize between 48 and 52%. Significant trends during baseline phase occurred for three participants (C, F, E) via the C statistic ( $Z = 2.09, 2.72, \text{ and } 2.48$ ),

negating further analysis. Only participant D demonstrated a therapeutic trend across the baseline and intervention phases. All participants increased the number of points within the 48-52% band between baseline and intervention phases, though participant C was the only one with three consecutive points within the band during the intervention phase. The average IRD for WBS was small (0.38).

#### **Center of pressure area.**

Difficulties with data retrieval and equipment malfunction occurred during COP testing, thus data points are missing from the baseline and intervention phases of all participants. Participants D and E were unable to complete the EC portion of the COP testing. Figures 4.7 and 4.8 present the results for COP area EO and EC. It should be noted that the y-axis scale is the same for all participants for EO, except participant E whose was much larger. Table 4.5 presents descriptive statistics and the statistical analysis of the EO and EC results. Hypothesized results for COP area were to decrease the area with EO and EC.

#### ***Eyes open.***

Results are displayed in Figure 4.7. No significant trends were identified during the baseline phase for any participant, though there was high variability with participants C and D. Therapeutic decreasing trends were found in participants A and C ( $Z= 1.74, 4.42$ ) during the intervention phase. Participant E had three consecutive sessions below his lower SD band. The average IRD across the three participants was 0.89.

#### ***Eyes closed.***

Figure 4.8 displays the results of the COP area with EC for three participants (A, C, F). The baseline phases varied among participants, but no significant trends were found. During the intervention phase participants A ( $Z= 2.16$ ) and C had significant decreases in COP area with EC, while participant F did not. A *C* statistic was unable to be calculated due to missing data points in the baseline phase for participant C, but an IRD was calculated based upon improvement made via SD band assessment. The average IRD was 0.84, indicating a large change.

### **Center of pressure velocity.**

As stated previously there were difficulties with data retrieval and equipment malfunction during COP testing, thus data points are missing. Figure 4.9 presents the results for EO, while Figure 4.10 presents the results for EC for three participants. Table 4.6 presents descriptive statistics and the statistical analysis of the EO and EC results. It was hypothesized there would be a decrease in COP velocity during and following intervention with EO and EC.

#### ***Eyes open.***

COP velocity with EO results are presented in Figure 4.9. The results from the *C* statistic and IRD are presented in Table 4.6. A significant counter-therapeutic trend ( $Z=3.44$ ) for velocity was found for participant A during intervention. No other participants demonstrated any significant trends across the baseline and intervention phases for their COP velocity with EO. Participant A's IRD indicated a moderate change (0.63).

#### ***Eyes closed.***

Figure 4.10 presents the COP velocity EC results for participants A, C, and F. Table 4.6 presents the descriptive data and statistical results for COP velocity with EC. *C* statistic analysis was only performed on participants A and F, and not performed on participant C due to the limited number of data points. No significant trends were established during the baseline phase for any participant, and participant A had a significant decreasing trend ( $Z=2.68$ ) during the intervention phase. His IRD indicated a large (1.00) therapeutic change.

### **Time to boundary mean minima: Anterior-Posterior**

#### ***Eyes open.***

Figure 4.11 presents the results for TTB mean minima AP with EO, with a larger y-axis for participant A. It was hypothesized there would be an increase in TTB mean minima. Table 4.7 presents the statistical analysis of the TTB mean minima data. Due to the limited number of baseline sessions a *C* statistic was not calculated for participant C. There were no significant therapeutic trends during baseline or intervention phases for participants A, D, and E. Participant F was the only participant with a counter-therapeutic

significant trend ( $Z= 1.93$ ) during intervention, though participant A also demonstrated counter-therapeutic changes with three consecutive sessions below his lower SD band. Their average IRD was 0.85.

***Eyes closed.***

The results for 3 participants TTB mean minima with EC for the AP direction are in Figure 4.12 and Table 4.7. During baseline phase participant A was stable, participant C appeared to be decreasing, but was missing data and participant F was increasing ( $Z= 1.69$ ). Of the three participants, only participant A had a significant therapeutic trend ( $Z= 2.03$ ) during intervention. There was a visual increasing trend of participant C during intervention that could not be supported, and he did not have enough consecutive points above the upper SD band to support calculating an IRD. The IRD for participant A's TTB mean minima with EC in the AP direction indicated a moderate therapeutic change (0.63).

**Time to boundary mean minima: Medial-Lateral.**

***Eyes open.***

Figure 4.13 and Table 4.7 presents the results for TTB mean minima ML with EO. The y-axis of participant A is significantly larger than other participants. TTB mean minima ML was hypothesized to increase during and following intervention. There were no significant trends for any participant in either baseline or intervention phases, nor were there any instances of significant changes in behavior based upon the SD band assessment.

***Eyes closed.***

Figure 4.14 and Table 4.7 presents the EC results for three participants with TTB mean minima in the ML direction. There were no significant changes in TTB mean minima ML with EC for any participant via the *C* statistic or SD band method.

**Time to boundary standard deviation: Anterior posterior**

***Eyes open.***

Figure 4.15 and Table 4.8 present the results for TTB SD in the AP direction with EO. TTB SD was hypothesized to increase. The baseline phases for all participants were



stable with no significant trends. No significant trends were observed during the intervention phase, though participants D and F both had significant consecutive sessions outside of their SD bands. Participant D had four consecutive sessions above her upper SD band and a small therapeutic IRD (0.06). Participant F had eight consecutive sessions below her lower SD band and a large counter-therapeutic IRD (1.00). A visual therapeutic trend was observed for participant C, but a *C* statistic could not be calculated to confirm or refute this. The average IRD for participants D and F indicated an overall moderate change (0.52).

#### ***Eyes closed.***

The results for EC of the TTB SD in the AP direction are presented in Figure 4.16 and Table 4.8. The baseline phase for each participant presented different patterns, but none had significant trends. Only participant A had a significant therapeutic trend ( $Z=2.50$ ) in TTB mean minima with EC in the AP direction. No other participants had significant changes. His IRD indicated a large therapeutic change (1.00).

#### **Time to boundary standard deviation: Medial-Lateral.**

#### ***Eyes open.***

Figure 4.17 and Table 4.8 present the results for TTB SD in the ML direction with EO. All participants had stable baseline phases, with no significant trends. During intervention only participant F had a significant trend ( $Z=2.09$ ). His IRD indicated a large therapeutic change (1.00).

#### ***Eyes closed.***

Figure 4.18 and Table 4.8 present the EC results of TTB SD in the ML direction. None of the participants had significant trends during baseline and intervention, or met the *a priori* criteria for change with SD band analysis.

#### **Single leg stance time.**

Figure 4.19 and Table 4.9 presents the results for SLST. The baseline phases for all participants were stable with no significant trends. No significant trends were observed during intervention phase, though *C* statistics were unable to be calculated for

participants A and D. Participant A repeatedly completed the maximum allotted time for the measure, 30 seconds, during baseline, intervention, and at maintenance follow-up. He was the only participant to maximize the measure. An IRD was calculated for participant D, who increased her SLST, and indicated a large change (1.00).

### **Gait Velocity**

Results of GV are presented in Figure 4.20. Statistical results for GV are presented in Table 4.10. All participants except E ( $Z= 1.67$ , counter-therapeutic) had a non-significant *C* statistic during the baseline phase, thus further analysis was conducted. A significant increasing GV trend via the *C* statistic was found for participants A ( $Z= 3.64$ ), D ( $Z= 2.63$ ) and F ( $Z= 1.73$ ) during intervention. The average IRD (0.72) for these participants found large changes in GV.

### **Strength of the Hip Abductors**

Figure 4.21 and Table 4.11 present the results for HAS. All participants had non-significant *C* statistic trends at baseline, allowing for further investigation of the intervention phase data. Participants C and F had significant increasing trends ( $Z= 2.24$ , 1.74) across the baseline and intervention phases. Their average IRD was 0.31, which was a small change.

### **Activities Scale for Kids**

The results for ASKp for are displayed in Figure 4. 22. Return rates of the ASKp were poor. Participant A and D each returned 1 baseline and 2 intervention surveys, while participant C returned one each from baseline and intervention. Participants E and F did not return any ASKp. Participant A displayed small improvements in his total score from baseline, while participants C and D made minimal changes from their baseline scores. Due to the limited number of returns no statistical analysis could be performed.

### **Games**

#### **Enjoyment and difficulty questionnaire.**

The participant results of the EDQ are presented in Figure 4.23, while average results are presented in Figure 4.24. Participant E refused to answer the EDQ repeatedly.

Participant A found the intervention difficult at the beginning, but reported it became easier. His enjoyment did not change; he reported that it was lots of fun. Participant C also reported that the intervention was difficult in the beginning and then plateaued in difficulty. He reported that it was enjoyable, but the last half of the intervention was less enjoyable. Participant D demonstrated the greatest variability in her ratings. She began with the intervention being difficult and enjoyable and then transitioned to it becoming easier and enjoyable. She reported the majority of the sessions being difficult. Participant F reported the intervention was enjoyable and not challenging throughout the entire intervention phase. The average results from the four participants in Figure 4.24 indicate the intervention was challenging in the beginning and less so as the intervention progressed. Overall, the enjoyment of the intervention varied minimally, with most participants reporting it to be lots of fun.

#### **Mastery of games.**

##### ***Medial-Lateral games.***

Figures 4.23 through 4.27 present averages scores for ML games, PS, SH and SK. All participants increased their scores of PS and SH during the intervention phase, except for participant E. For SH, participant A demonstrated the greatest improvements in score. Participants A, C and F progressed to the highest difficult setting of SH, while participants D and E remained at the beginner setting. In SK, participants D and F had clear decreases in time to complete the game, while participants A and C overall trends were flat across intervention. Participant E increased his time to complete SK, thus decreasing his score. Only participant A progressed to the highest difficulty setting of SK.

##### ***Multi-Directional games.***

Figures 4.28 through 4.30 present the average results for BB, TT, and SN. All participants increased their scores of the BB during the intervention phase except participant E. Participant A progressed through all the difficulty settings of BB, while participants C, D, E and F remained at the beginner setting. Participants A and D had steady increases in their TT scores across the intervention phase. Participant C had sporadic increases in his TT scores without any consistent patterns, while participant F

remained consistent. Participant E decreased initially and then remained consistent throughout. Participant A progressed through all three of the difficulty settings of TT, while participants C, D, E and F remained at the beginner setting. Overall trends for the participants for the SN were flat or slightly decreasing in time. Participant A demonstrated the greatest variability in his average SN scores and largest decreasing trends within his data and was the only participant to progress to the highest difficulty setting.

### **Discussion**

Four children with DD successfully completed a supervised 6 week 3 times per week video-game based balance training intervention. The participants were assessed for body structures and functions including balance, HAS and GV, as well as activities and participation through the ASKp and EDQ. Minimal changes were found across the measures.

### **Measures of Body Structure and Function**

#### **Balance.**

The clinical measure of balance, SLST, proved to be a challenge for 3 of the 5 participants. Most participants had not previously been expected to stand on one limb for any period of time other than what was required during gait. The only participant to make clear improvements in SLST was participant D, who at the beginning of the study could not maintain SLS. Her improvement in SLST did exceed her SEM established with reliability data, indicating a significant therapeutic change. Participant A met a ceiling effect of SLST during the baseline phase, not allowing him any opportunity to improve. Most studies that investigate static balance abilities for children with DD choose dual limb postures, though SLST has been found to be a valid and reliable measure for children with CP (Liao et al., 2001; Zaino et al., 2004) and can be used for children with DS (Villamonte et al., 2010). With only one participant making improvements in SLST these results suggest a dual limb stance balance-training program has minimal effects on SLST for children with DD. Similar results were found in Hartveld and Hagerty's (1996) balance training intervention study, where one participant demonstrated no change and

the other steadily improved SLST. Recently De Kegel and colleagues (2010) explored SLST and COP measures for TD children and found that while SLST with EO was not sensitive enough to distinguish significantly between TD children and children with hearing impairments, SLST with EC was discriminative. The participants from this study likely would have been unable to maintain SLS with EC due to the minimal experience with SLS. Based on the results from this study and De Kegel and colleagues' (2010) recommendation SLS should be included in the balance assessment and intervention protocols for children with DD. Specific training of SLS may increase SLST, since the results of this study demonstrate that dual-limb stance training did not increase SLST. Increasing SLST is important because SLS is used frequently in everyday activities, such as stair climbing, dressing, and bathing, and increased SLS may foster independence.

In contrast to the clinical measure, COP area and velocity results were more sensitive to changes in balance abilities. Participant A made changes in all dimensions and conditions of COP testing but was the only participant to do so. His therapeutic changes are important because children with ASD have increased sway velocity (Fournier, Kimberg, et al., 2010) and area (Fournier, Kimberg, et al., 2010; Kohen-Raz et al., 1992; Minsheiw et al., 2004). Improvements were found in COP area also for participants C (EO, EC) and E (EO). While COP area has not been used as an outcome measure for children with DD, following stroke adults have demonstrated decreases in COP area following balance training (Tsaklis, Grooten, & Franzen, 2012; Zijlstra, Mancini, Chiari, & Zijlstra, 2010). The closest reference to COP area for children with DD is in Ledebt and colleagues (2005) study where they reported a decrease in COP amplitude with EO for children with hemiplegic CP following balance training. In this study, in contrast to the pilot study, the one participant with spastic diplegia CP (F) had no changes in COP area or velocity. Pilot study data (Chapter 3) for children with spastic diplegia CP demonstrated changes in 2 of the 3 participants. Participant F's distinguishing characteristic from the pilot study data is that he was overweight, with a body mass index of 19.1, while the participants from the pilot study had body mass indexes within the normal range. In TD children, especially boys, it has been reported that they have larger COP mean radius in quiet stance with EO and EC (Lee & Lin, 2007), thus his weight may have been influencing his postural control abilities. The only other

participant to demonstrate changes in COP area was participant E, who did not complete the entire intervention. During his intervention phase, participant E displayed a significantly decreasing COP area with EO, and recent literature supports that children with DS have improved postural control following balance training with the Wii (Berg et al., 2012).

The TTB mean minima and SD data did not show consistent improvements in the participants, in fact many participants changed from relatively stable baselines to increased variability during intervention phase. Increased (therapeutic) TTB mean minima for AP direction was found for participant A with EC, while therapeutic changes were observed in TTB SD for participants A (EC) and D (EO). Two participants demonstrated decreases (counter-therapeutic) in TTB mean minima AP with EO (A, F), and participant F also decreased TTB SD AP with EO. It is difficult to make comparisons with the TTB data as the majority of research utilizing TTB has been with healthy adults or adults with chronic ankle instability. While TTB to boundary has been utilized in adults with neurological dysfunction, it was a comparison study and not an intervention study (van Wegen et al., 2001). For those studies that have used TTB as an outcome measure following intervention positive changes were reported in AP mean minima and SD as well as ML mean minima with EC (McKeon et al., 2008), while Hoch and McKeon (2011) reported changes with the same variables but with EO. It is important to note that these two studies used a SLS protocol for TTB and not dual as in this study. None of these authors (Hoch & McKeon, 2011; McKeon et al., 2008) reported decreases in TTB scores following intervention. Counter-therapeutic trends were observed for participants A (mean minima AP EO) and F (mean minima and SD AP EO). The counter-therapeutic trend for participant A may be explained by leg pain that he reported periodically, as it has been reported that leg pain increases sway velocity in healthy adults (Hirata, Arendt-Nielsen, Shiozawa, & Graven-Nielsen, 2011; Hirata, Ervilha, Arendt-Nielsen, & Graven-Nielsen, 2011). The decreases observed with participant F may be explained by his small variability during baseline phase for both variables. During the intervention phase he had increased variability, with more sessions falling below the baseline mean, creating the negative trend (mean minima AP EO) and increased number of points below the lower SD band (SD AP EO).

While it has been reported that children with DD have greater difficulty controlling ML movements, in this study the improvements occurred primarily in the AP direction (Black et al., 2007; Hsue et al., 2009a, 2009b; Kubo & Ulrich, 2006a). Participant F was the only participant to demonstrate a therapeutic change in the ML direction (SD with EO). Changes in the ML direction following balance training has been reported with COP measures for children with CP (Ledebt et al., 2005), and participant F's diagnosis was CP. While 15 minutes of each intervention session was focused on lateral weight shifting it did not provide sufficient stimulus to increase ML control.

The laboratory measures suggest that changes were occurring during the intervention phase with most participants increasing their variability during the intervention as compared to their baseline phase. Though significant changes did not occur for the majority of participants, the intervention was influencing their variability between sessions. The increased variability, as well as the counter-therapeutic findings, may indicate a learning stage for these participants. When learning, or modifying, a task the variability increases before returning to previous levels (Adi-Japha, Karni, Parnes, Loewenschuss, & Vakil, 2008; Adolph, 2008; Adolph & Robinson, 2008; Kamm et al., 1990; Thelen et al., 1996).

As in the pilot study, two participants were able to make significant changes in their WBS as measured by the Wii balance board. The results from this study still do not support the use of the output from the WiiFit software as an outcome measure to be used in clinical practice. The two participants that made improvements in WBS had no changes in measures of ML control with TTB. The measure of WBS from the WiiFit does not appear to be sensitive enough to detect changes.

With so few changes in measures of balance the use of the WiiFit balance games alone does not appear to have significant therapeutic effects. In planning interventions for children with DD the WiiFit balance games alone with the rigid schedule utilized here will not be sufficient to make measurable changes. While the children made improvements in the games, indicating increases in motor control and coordination, these did not transfer to the process of postural control, or balance abilities. The weight shifting utilized during game play was insufficient to challenge the sensory and motor systems responsible for postural control.

### **Gait velocity.**

Three of the five participants demonstrated significant increases in GV during this study, with an IRD indicating a large change. All of the participants had slower GV at baseline than what has been reported for their TD peers (Dusing & Thorpe, 2007; Katz-Leurer et al., 2008). The baseline results for these participants more closely resemble the GVs of children with CP (Eagleton et al., 2004; Katz-Leurer et al., 2009). In contrast to the pilot study these participants, by having a slower GV, had the opportunity to make increases. Increased GV following balance training has been reported for children with DD (Ledebt et al., 2005). Using the SEM from reliability data clinically meaningful changes occurred in GV for participants A ( $GV \geq 0.786$ ) and D ( $GV \geq 0.592$ ), while participant F was close ( $GV \geq 0.896$ ) based on intervention mean data (Table 4.10). Improvements in GV suggest that the participants were able to improve the natural rhythm that occurs during gait, which is impaired in children with CP (Liao et al., 1997).

### **Hip abductor strength.**

HAS was hypothesized to remain constant throughout the study. Three of participants demonstrated no change in HAS, while two participants significantly increased their HAS during the intervention. While the average IRD indicates it was a mild increase in HAS, there was still significant change. Participant F while had a significant increasing HAS trend did not have a clinically meaningful change based on his SEM from the reliability data. Most research uses strength training to improve balance (Gupta, Rao, & S, 2011; Mercer, Chang, Williams, Noble, & Vance, 2009; Tsimaras & Fotiadou, 2004) and this is a unique study that found balance training to increase strength in children with DD. Hip abductors are commonly cited to be weak in the balance (Lowe et al., 2004), gait (Metaxiotis et al., 2000) and function literature (Dichter, 1994; Eek & Beckung, 2008; Ross & Engsberg, 2007). Diagnoses of those with improvements in HAS included children with CP and sensory processing disorder. The hip abductors are used for stability of the pelvis and weight shifting ability during gait (Metaxiotis et al., 2000). Only participant F (CP) demonstrated therapeutic changes in both HAS and GV, as well as increased TTB SD ML with EO, further supporting the relationship between HAS and GV and balance abilities.



## **Measures of Activity Limitations and Participation**

### **Activities Scale for Kids, performance version.**

The poor return rate for the ASKp made it difficult to analyze the effects of the balance training intervention on the activities and participation of participants. Of the few returned there were no changes observed between the baseline and intervention scores. None of the participants reached a ceiling effect for the tool, and all had significant room for improvement.

### **Limitations**

Two of the participants did not complete the entire study and both were children with DS, thus the results of this study are limited to children with ASD, CP, developmental delay and sensory processing disorder. While it is important to investigate how interventions affect different diagnoses, the wide range of diagnoses included here may have been more detrimental than helpful. It is difficult to make suggestions about the influence of the diagnosis on the intervention when there were no replicated diagnoses.

The poor return rate of the ASKp is another major limitation. In the pilot study significant improvements were found with the ASKp and this was not replicated with this study. The reliability data was collected with 3 raters rather than the 2 originally planned, which may have introduced extra error. There were also problems accessing some COP data for TTB analysis. Counter-therapeutic trends were observed in participants A and F for COP and TTB measures. While the negative trends in participant A may be explained by pain and those in participant F by his weight, there is no clear explanation for why these participants demonstrated counter therapeutic trends.

### **Suggestions for Future Research**

Further replication of this study is needed with more children of each diagnosis to allow for better extrapolation of the data. This study could be repeated as an independent home program with weekly therapist monitoring, rather than therapist directed at each intervention session. SLS should continue to be incorporated into future research, with the option of EC when appropriate. Based on the results from this study and the pilot study, WBS, should not continue to be used for research or clinical purposes. Expanding

the intervention to 8 weeks or increasing the intensity to 4 to 5 times per week over a shorter duration may also be advisable. While the results from this study support further exploration, it may be important to assess things such as reaction time or anticipatory postural adjustments (Liu et al., 2009a), as these may also be changing.

### **Conclusion**

A 6 week, 3 times per week for 30 minutes therapist supervised video-game based balance training intervention for children with DD was explored for its effect on balance, GV, HAS and activities. Laboratory measures of balance (COP area EO and EC) supported small changes in temporal and spatial measures of balance for all participants. The clinical measure of balance (SLST) did not demonstrate significant increases, but it was a challenging activity for the participants. Increases in GV were observed in 3 of the 5 participants, and increases in HAS were found for 2 participants. No changes were found in the activities and participation of the participants, though all enjoyed the intervention and found it to be challenging. Counter therapeutic changes were found for two participants in laboratory measures of balance, though they returned to baseline values at follow up.

Table 4.1

*Participant Demographics*

Participant	Age (years, months)	Gender	Diagnosis	Equipment	Therapies Receiving
A	9, 7	Male	Asperger/Autism spectrum disorder; attention deficit hyperactivity disorder; anxiety	none	<u>School Based:</u> None <u>Private:</u> OT 60 minutes 2X per month
B		Female	Down syndrome (trisomy 21)	none	<u>School Based:</u> None <u>Private:</u>
C		Male	Sensory processing disorder	none	<u>School Based:</u> None <u>Private:</u> OT 30 minutes 1X per week
D	5, 9	Female	Developmental delay; scoliosis; congenital left radius dislocation	Bilateral SMOs; back brace; rolling walker for extremely long distances; glasses	<u>School Based:</u> PT 30 minutes 1X per week; OT 30 minutes 1X per week; SLP 30 minutes 1X per week <u>Private:</u> PT 45 minutes 3X per month; OT 45 minutes 3X per month; SLP 45 minutes 3X per month
F	10, 7	Male	Down syndrome (trisomy 21)	Bilateral arch supports; glasses	<u>School Based:</u> OT 30 minutes 2X per week; SLP 30 minutes 2X per week <u>Private:</u> None
E	7, 0	Male	Spastic diplegia cerebral palsy (GMFCS II); hypoplasia of the left optic nerve	Bilateral hinged AFOs; rolling walker with seat for long distances; glasses	<u>School based:</u> PT 2X per month <u>Private:</u> OT 30 minutes 1X week

*Note.* OT= occupational therapy; PT= physical therapy; SLP= speech language pathology; SMO= supra-malleolar orthosis; GMFCS=

Gross Motor Function Classification System; AFO= ankle foot orthosis

Table 4.2

*Intervention Summary*

Participant	Range (minutes)	Mean (minutes)	SD
A	9-31	26	7
C	15-30	26	4
D	26-31	28	1
E	20-26	24	2
F	26-30	29	1
All participants	9-31	27	4

Table 4.3

*Interrater Reliability Results*

Participant	Raters	Single Leg Stance Time		Gait Velocity		Hip Abductor Strength	
		r	SEM	r	SEM	r	SEM
A	PT, OT			0.693	0.018	0.918	0.738
D	PT, OT	0.835	0.182	0.957	0.037	-1.721	2.920
F	PT, PT	0.776	0.181	0.895	0.039	0.040	1.789

*Note.* R= Pearson correlation; SEM= standard error of measure; PT= physical therapist; OT= occupational therapist

Table 4.4

*Weight Bearing Symmetry Results*

Participant	Phase	<i>M</i>		<i>C</i>		Points within 48-52% range
		(%)	<i>SD</i>	( <i>Z</i> )	IRD	
A	Baseline	49.7	6.7	0.26 (0.76)		2
	Intervention	51.0	5.0	0.08 (0.42)		5
	Maintenance	52.1				0
C	Baseline	47.1	3.9	0.71 (2.09)*		1
	Intervention	51.3	9.2		0.52	4
	Maintenance	48.0				1
D	Baseline	42.8	4.1	0.20 (0.61)		1
	Intervention	47.1	5.7	0.52 (2.72)*	0.10	4
	Maintenance	46.4				0
F	Baseline	49.7	2.8	-0.58 (-1.72)*		5
	Intervention	51.8	5.8			6
	Maintenance	46.9				0
E	Baseline	46.9	4.1	0.77 (2.48)*		4
	Intervention	47.7	6.9			1

*Note.* *C* = *C* statistic; *Z* = *Z* score; IRD = improvement rate difference

\*  $p < .05$

Table 4.5

*Center of Pressure Area Results*

Participant	Phase	Condition	M (cm <sup>2</sup> )	SD	C (Z)	IRD
A	Baseline	Eyes Open	0.879	0.321	0.246 (0.673)	
		Eyes Closed	2.107	1.024	0.325 (0.891)	
	Intervention	Eyes Open	2.050	0.990	0.361 (1.738)*	0.683
		Eyes Closed	3.327	1.467	0.448 (2.157)*	0.683
	Maintenance	Eyes Open	0.421			
		Eyes Closed	1.172			
C	Baseline	Eyes Open	4.224	1.584	0.410 (1.158)	
		Eyes Closed	6.990	0.201		
	Intervention	Eyes Open	5.396	2.034	0.939 (4.421)*	1.000
		Eyes Closed	6.285	2.822		1.000
	Maintenance	Eyes Open	0.9933			
		Eyes Closed	3.227			
D	Baseline	Eyes Open	9.594	1.799	0.342 (0.937)	
	Intervention	Eyes Open	9.148	2.935	0.085 (0.407)	
	Maintenance	Eyes Open	9.291			
F	Baseline	Eyes Open	4.533	2.777	0.458 (1.296)	
		Eyes Closed	6.758	2.391	0.020 (0.056)	
	Intervention	Eyes Open	2.984	0.915	0.305 (1.470)	
		Eyes Closed	6.465	2.542	0.185 (0.889)	
	Maintenance	Eyes Open	2.371			
		Eyes Closed	3.786			
E	Baseline	Eyes Open	134.847	27.868	0.208 (0.616)	
	Intervention	Eyes Open	104.557	42.018	0.527 (1.928)	1.000

Note. C= C statistic; Z= Z score; IRD= improvement rate difference

\* p< .05

Table 4.6

*Center of Pressure Velocity Results*

Participant	Phase	Condition	M (cm/s)	SD	C (Z)	IRD
A	Baseline	Eyes Open	1.261	0.058	0.030 (0.082)	
		Eyes Closed	1.868	0.354	0.012 (0.033)	
	Intervention	Eyes Open	1.429	0.211	0.715 (3.442)*	0.632
		Eyes Closed	1.973	0.357	0.557 (2.681)*	1.000
	Maintenance	Eyes Open	1.143			
		Eyes Closed	1.172			
C	Baseline	Eyes Open	3.377	0.910	0.367 (1.039)	
		Eyes Closed	4.658	1.471		
	Intervention	Eyes Open	3.710	0.918	0.308 (1.450)	
		Eyes Closed	3.423	1.067		
	Maintenance	Eyes Open	3.172			
		Eyes Closed	3.227			
D	Baseline	Eyes Open	5.715	0.765	0.065 (0.177)	
	Intervention	Eyes Open	5.482	1.670	0.2663 (1.282)	
	Maintenance	Eyes Open	5.566			
F	Baseline	Eyes Open	2.553	0.350	0.220 (0.622)	
		Eyes Closed	3.497	0.803	0.162 (0.459)	
	Intervention	Eyes Open	2.635	0.378	0.161 (0.775)	
		Eyes Closed	3.437	0.667	0.066 (0.317)	
	Maintenance	Eyes Open	2.312			
		Eyes Closed	2.505			
E	Baseline	Eyes Open	11.767	1.868	0.391 (1.155)	
	Intervention	Eyes Open	9.277	3.585	0.354 (1.292)	

Note. C= C statistic; Z= Z score; IRD= improvement rate difference

\* p< .05



Table 4.7

*Time to Boundary Mean Minima Results*

Participant	Phase	Condition	<i>M</i> (s)	<i>SD</i>	<i>C</i> ( <i>Z</i> )	IRD
<i>Anterior-Posterior Direction</i>						
A	Baseline	Eyes Open	18.93	0.91	0.37 (1.06)	
		Eyes Closed	11.06	3.11	0.42 (1.16)	
	Intervention	Eyes Open	16.01	3.06	0.21 (0.97)	1.00
		Eyes Closed	10.66	2.31	0.42 (2.03)*	0.63
	Maintenance	Eyes Open	20.79			
		Eyes Closed	18.39			
C	Baseline	Eyes Open	6.81	1.34		
		Eyes Closed	4.86	1.73		
	Intervention	Eyes Open	7.40	1.39		
		Eyes Closed	6.21	1.79		
	Maintenance	Eyes Open	13.07			
		Eyes Closed	11.10			
D	Baseline	Eyes Open	1.78	0.28	0.49 (1.38)	
	Intervention	Eyes Open	1.99	0.56	0.14 (0.69)	
	Maintenance	Eyes Open	2.14			
F	Baseline	Eyes Open	9.29	1.18	0.31 (0.84)	
		Eyes Closed	5.15	0.99	0.62 (1.69)*	
	Intervention	Eyes Open	7.49	1.48	0.41 (1.93)*	0.69
		Eyes Closed	5.40	0.92		
	Maintenance	Eyes Open	9.66			
		Eyes Closed	6.89			
E	Baseline	Eyes Open	2.97	1.10	0.12 (0.36)	
	Intervention	Eyes Open	3.17	1.02	0.13 (0.56)	

Table 4.7 continued

Participant	Phase	Condition	M (s)	SD	C (Z)	IRD
<i>Medial-Lateral Direction</i>						
A	Baseline	Eyes Open	29.03	2.32	0.42 (1.19)	
		Eyes Closed	21.16	5.21	0.45 (1.24)	
	Intervention	Eyes Open	27.29	3.72	0.06 (0.27)	
		Eyes Closed	19.68	4.90	0.19 (0.93)	
	Maintenance	Eyes Open	20.23			
		Eyes Closed	18.76			
C	Baseline	Eyes Open	7.21	2.15		
		Eyes Closed	6.73	2.10		
	Intervention	Eyes Open	7.48	1.33		
		Eyes Closed	7.49	1.86		
	Maintenance	Eyes Open	8.99			
		Eyes Closed	8.28			
D	Baseline	Eyes Open	6.6142	0.99	0.18 (0.52)	
	Intervention	Eyes Open	5.99	1.47	0.18 (0.85)	
	Maintenance	Eyes Open	3.94			
F	Baseline	Eyes Open	11.55	4.29	0.41 (1.12)	
		Eyes Closed	7.22	2.96	0.17 (0.46)	
	Intervention	Eyes Open	13.28	2.89	0.15 (0.72)	
		Eyes Closed	8.41	2.57	0.03 (0.13)	
	Maintenance	Eyes Open	17.69			
		Eyes Closed	12.66			
E	Baseline	Eyes Open	3.71	1.23	0.06 (0.18)	
	Intervention	Eyes Open	5.68	3.11	0.14 (0.62)	

Note. C= C statistic; Z= Z score; IRD= improvement rate difference

\*p< .05

Table 4.8

*Time to Boundary Standard Deviation Results*

Participant	Phase	Condition	<i>M</i> (s)	<i>SD</i>	<i>C</i> ( <i>Z</i> )	IRD	
<i>Anterior-Posterior Direction</i>							
A	Baseline	Eyes Open	13.59	3.31	0.27 (0.75)	1.00	
		Eyes Closed	8.03	2.01	0.13 (0.36)		
	Intervention	Eyes Open	11.48	2.89	0.20 (0.95)		
		Eyes Closed	8.35	1.68	0.52 (2.50)*		
	C	Baseline	Eyes Open	4.79	0.51		
			Eyes Closed	3.75	1.27		
Intervention		Eyes Open	5.64	1.30			
		Eyes Closed	5.03	1.41			
D	Baseline	Eyes Open	1.57	0.02	0.06 (0.17)	0.06	
		Eyes Closed	8.06				
F	Intervention	Eyes Open	1.68	0.44	0.14 (0.67)		
		Eyes Closed	8.06				
	Maintenance	Eyes Open	1.79				
		Eyes Closed	8.06				
	E	Baseline	Eyes Open	7.37	0.71	0.01 (0.02)	1.00
			Eyes Closed	4.68	1.57	0.49 (1.34)	
Intervention		Eyes Open	5.55	1.08	0.26 (1.21)		
		Eyes Closed	4.50	1.02	0.25 (1.20)		
E	Maintenance	Eyes Open	6.80				
		Eyes Closed	4.53				
	Baseline	Eyes Open	2.74	1.28	0.34 (1.02)		
		Eyes Closed	4.53				
E	Intervention	Eyes Open	2.73	0.73	0.07 (0.30)		
		Eyes Closed					

Table 4.8 continued

Participant	Phase	Condition	<i>M</i> (s)	<i>SD</i>	<i>C</i> ( <i>Z</i> )	IRD
<i>Medial-Lateral Direction</i>						
A	Baseline	Eyes Open	18.42	0.93	0.49 (1.39)	
		Eyes Closed	16.56	3.59	0.24 (0.65)	
	Intervention	Eyes Open	19.43	2.68	0.21 (1.00)	
		Eyes Closed	14.55	3.52	0.05 (0.23)	
	Maintenance	Eyes Open	17.43			
		Eyes Closed	12.92			
C	Baseline	Eyes Open	5.24	0.67		
		Eyes Closed	4.76	0.72		
	Intervention	Eyes Open	5.31	1.26		
		Eyes Closed	5.49	1.57		
	Maintenance	Eyes Open	7.34			
		Eyes Closed	6.98			
D	Baseline	Eyes Open	4.42	0.17	0.34 (0.96)	
		Eyes Open	4.39	1.02	0.06 (0.28)	
	Maintenance	Eyes Open	2.49			
F	Baseline	Eyes Open	9.68	1.50	0.44 (1.21)	
		Eyes Closed	6.14	1.65	0.05 (0.15)	
	Intervention	Eyes Open	9.61	1.93	0.44 (2.09)*	1.00
		Eyes Closed	6.63	2.26	0.34 (1.58)	
	Maintenance	Eyes Open	10.86			
		Eyes Closed	8.41			
E	Baseline	Eyes Open	3.80	1.15	0.43 (1.28)	
	Intervention	Eyes Open	4.78	1.99	-0.15 (0.63)	

Note. *C*= *C* statistic; IRD= improvement rate difference

\**p*< .05

Table 4.9

*Single Limb Stance Time Results*

Participant	Phase	<i>M</i> (s)	<i>SD</i>	<i>C</i> ( <i>Z</i> )	IRD
A	Baseline	30.00			
	Intervention	30.00			
	Maintenance	30.00			
C	Baseline	4.17	1.25	0.13 (0.37)	
	Intervention	5.07	1.58	0.16 (0.64)	
	Maintenance	10.93			
D	Baseline	0.0			
	Intervention	0.70	0.41	0.71 (2.87)*	1.00
	Maintenance	0.58			
F	Baseline	1.08	0.36	0.00 (0.00)	
	Intervention	0.92	0.27	0.09 (0.34)	
	Maintenance	1.91			
E	Baseline	1.15	0.44	0.18 (0.57)	
	Intervention	1.39	0.67	0.17 (0.66)	

*Note.* C= C statistic; Z= Z score; IRD= improvement rate difference

\*p< .05

Table 4.10

*Gait Velocity Results*

Participant	Phase	<i>M</i> (m/s)	<i>SD</i>	<i>C</i> ( <i>Z</i> )	IRD
A	Baseline	0.75	0.05	0.09 (0.24)	
	Intervention	0.79	0.04	1.00 (3.64)*	0.86
	Maintenance	0.76			
C	Baseline	0.89	0.06	0.03 (0.08)	
	Intervention	0.98	0.09	0.16 (0.62)	
	Maintenance	0.89			
D	Baseline	0.52	0.07	0.39 (1.20)	
	Intervention	0.63	0.12	0.65 (2.63)*	0.43
	Maintenance	0.85			
F	Baseline	0.82	0.04	0.11 (0.33)	
	Intervention	0.84	0.07	0.66 (2.56)*	0.86
	Maintenance	1.00			
E	Baseline	0.75	0.11	0.52 (1.67)*	
	Intervention	0.79	0.15		

Note. *C*= *C* statistic; *Z*= *z* score; IRD= improvement rate difference

\*  $p < .05$

Table 4.11

*Hip Abductor Strength Results*

Participant	Side	Phase	<i>M</i> (lb)	<i>SD</i>	<i>C</i> ( <i>Z</i> )	IRD
A	Left	Baseline	30.7	2.3	0.09 (0.25)	
		Intervention	30.1	3.2	0.15 (0.56)	
		Maintenance	29.0			
C	Left	Baseline	7.8	1.2	0.25 (0.75)	
		Intervention	9.9	1.7	0.57 (2.24)*	0.40
		Maintenance	13.5			
D	Left	Baseline	11.8	1.9	0.37 (1.14)	
		Intervention	10.9	1.5	0.29 (1.16)	
		Maintenance	13.0			
F	Right	Baseline	10.6	0.5	0.03 (0.10)	
		Intervention	12.0	1.4	0.45 (1.74)*	0.21
		Maintenance	10.5			
E	Right	Baseline	4.1	0.7	0.09 (0.73)	
		Intervention	6.8	3.9	0.33 (1.26)	
		Maintenance				

*Note.* HAS= hip abductor strength; C= C statistic;

IRD= improvement rate difference

\* $p < .05$

Figure 4.1

*Single limb stance time*





Figure 4.2

*Baseline Phase Procedures for Participant A*

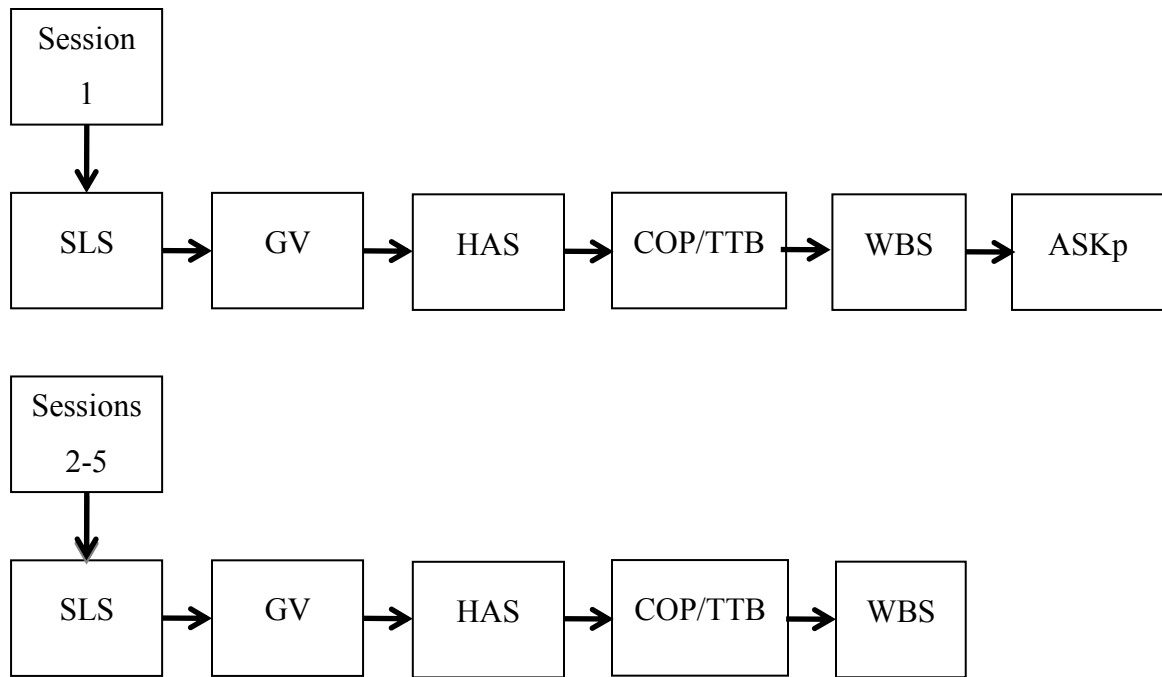
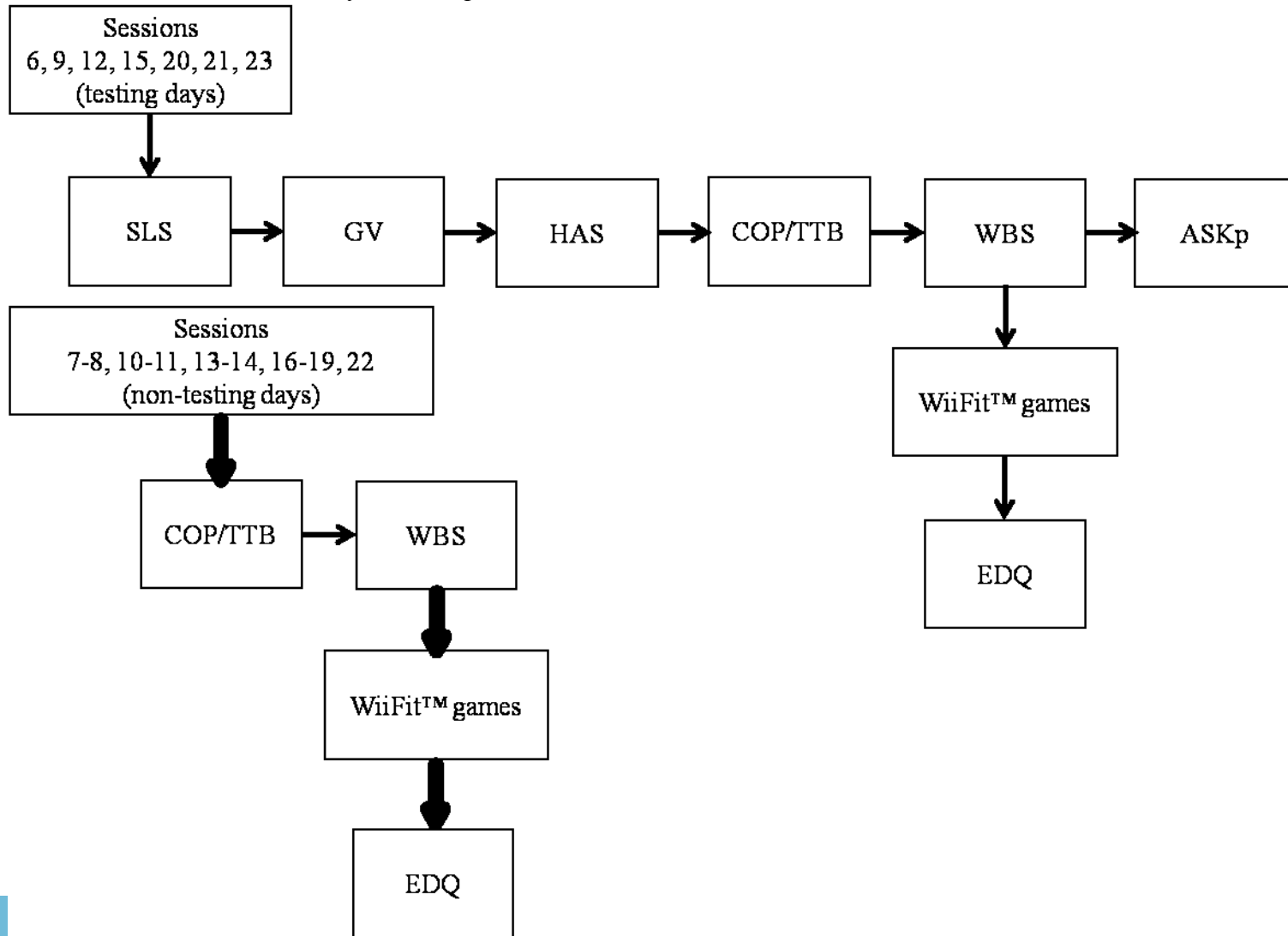


Figure 4.3

*Intervention Phase Procedures for Participant A*



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Figure 4.4

*Screen shots of Ski Slalom and Snowboard Slalom*

Ski Slalom



Snowboard Slalom



Figure 4.5

*Average number of rest breaks and activity change requests for all participants*

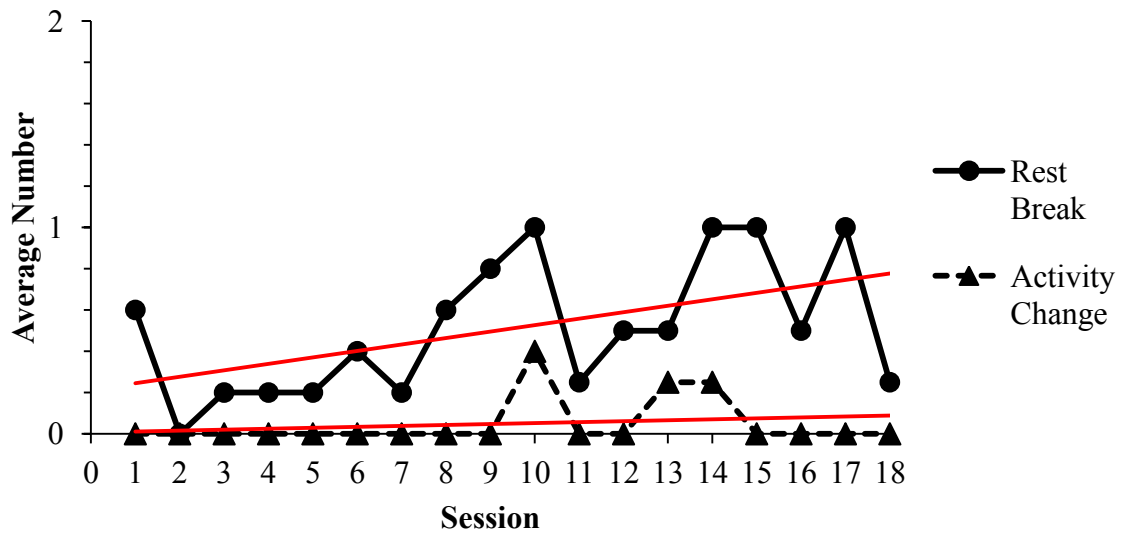


Figure 4.6

*Weight bearing symmetry results*

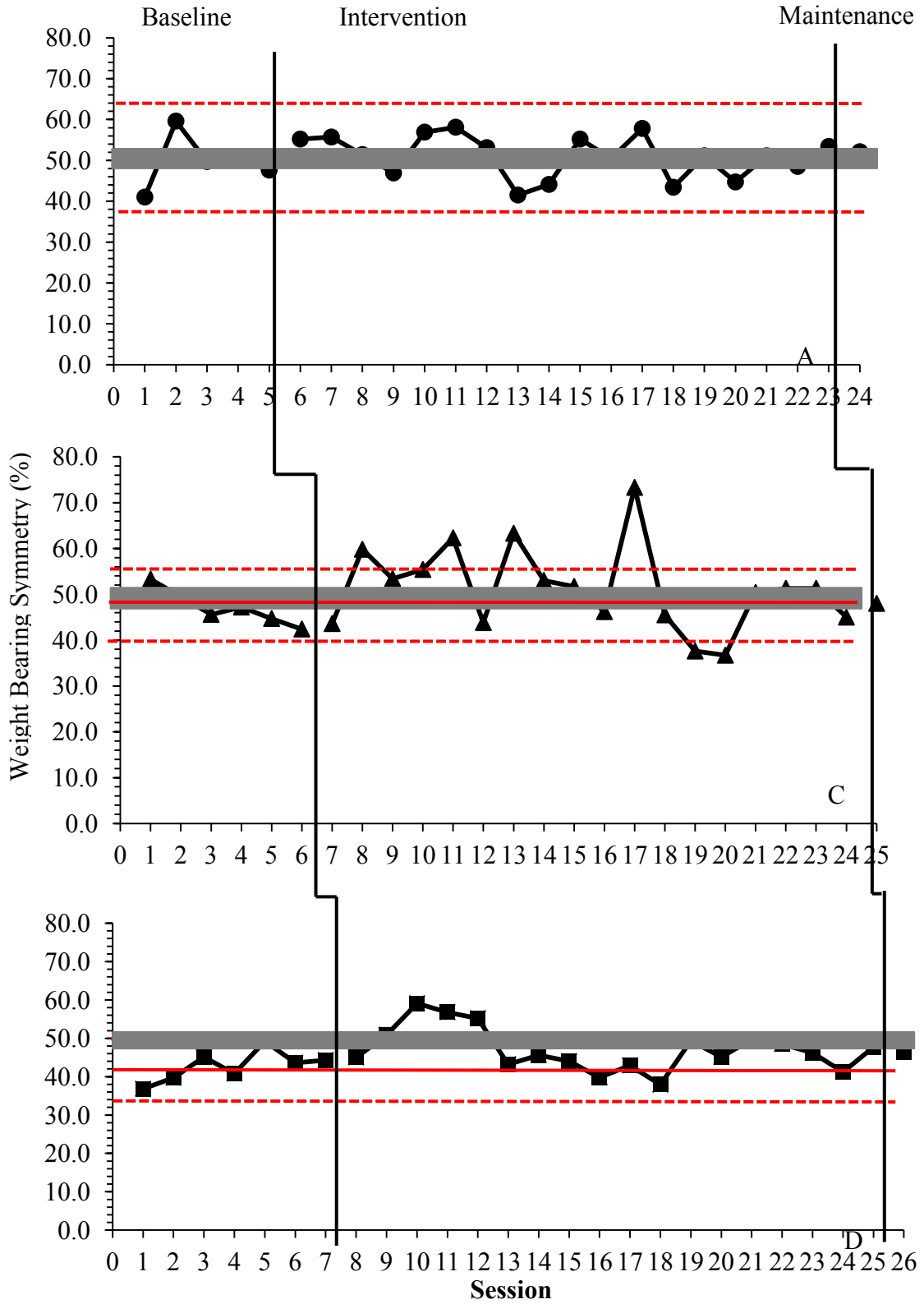


Figure 4.6 continued

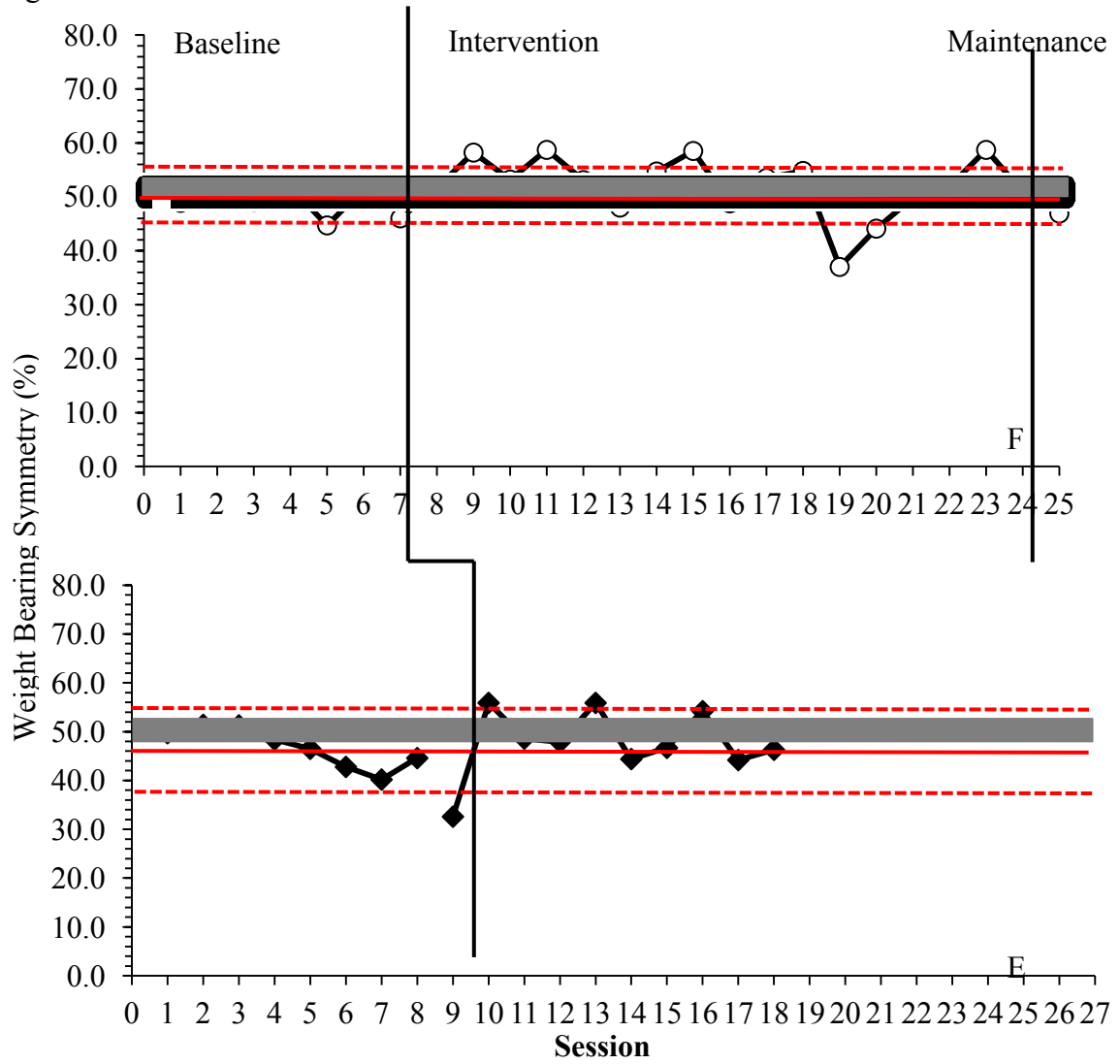


Figure 4.7

Center of Pressure Area with Eyes Open

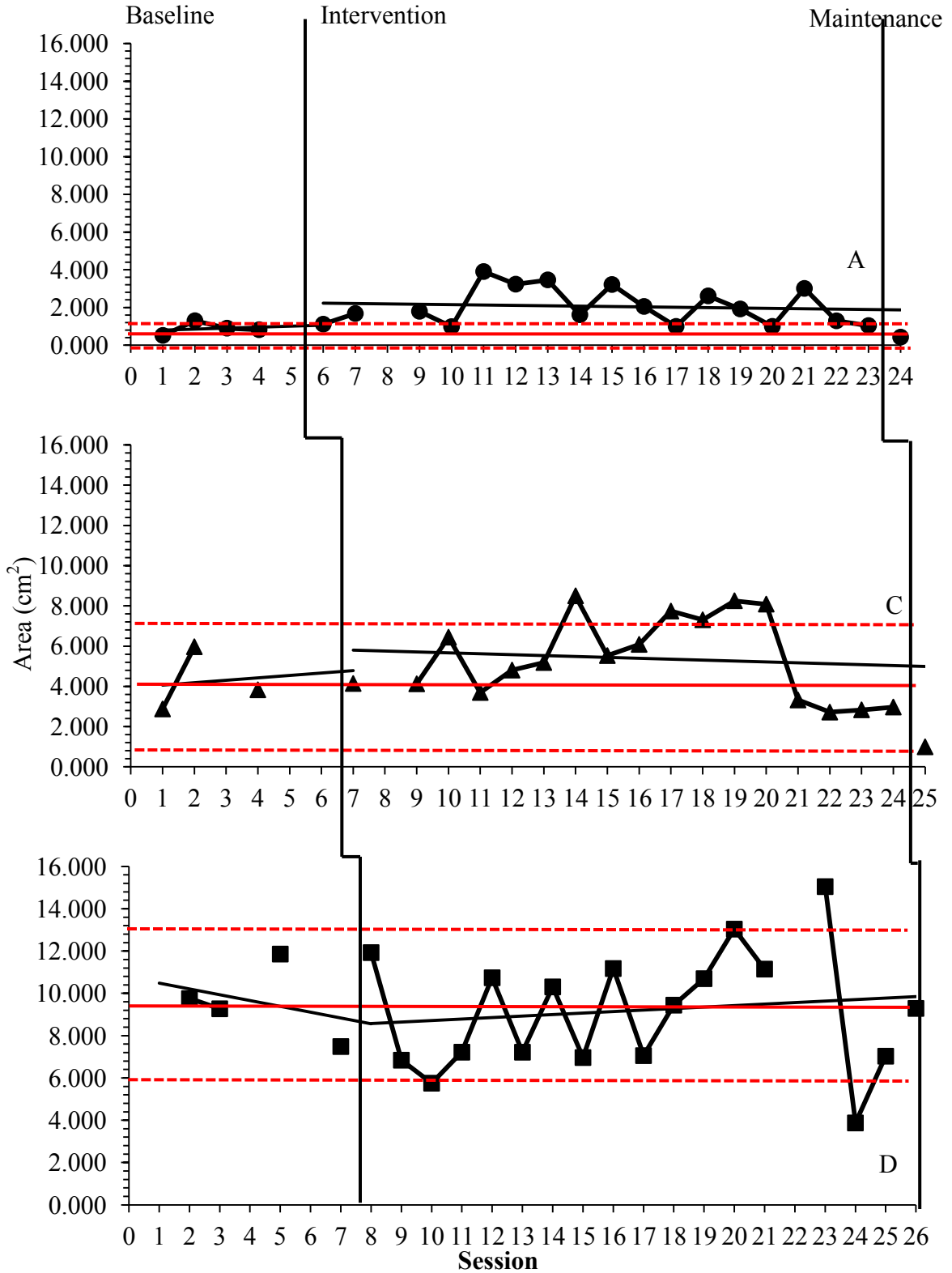
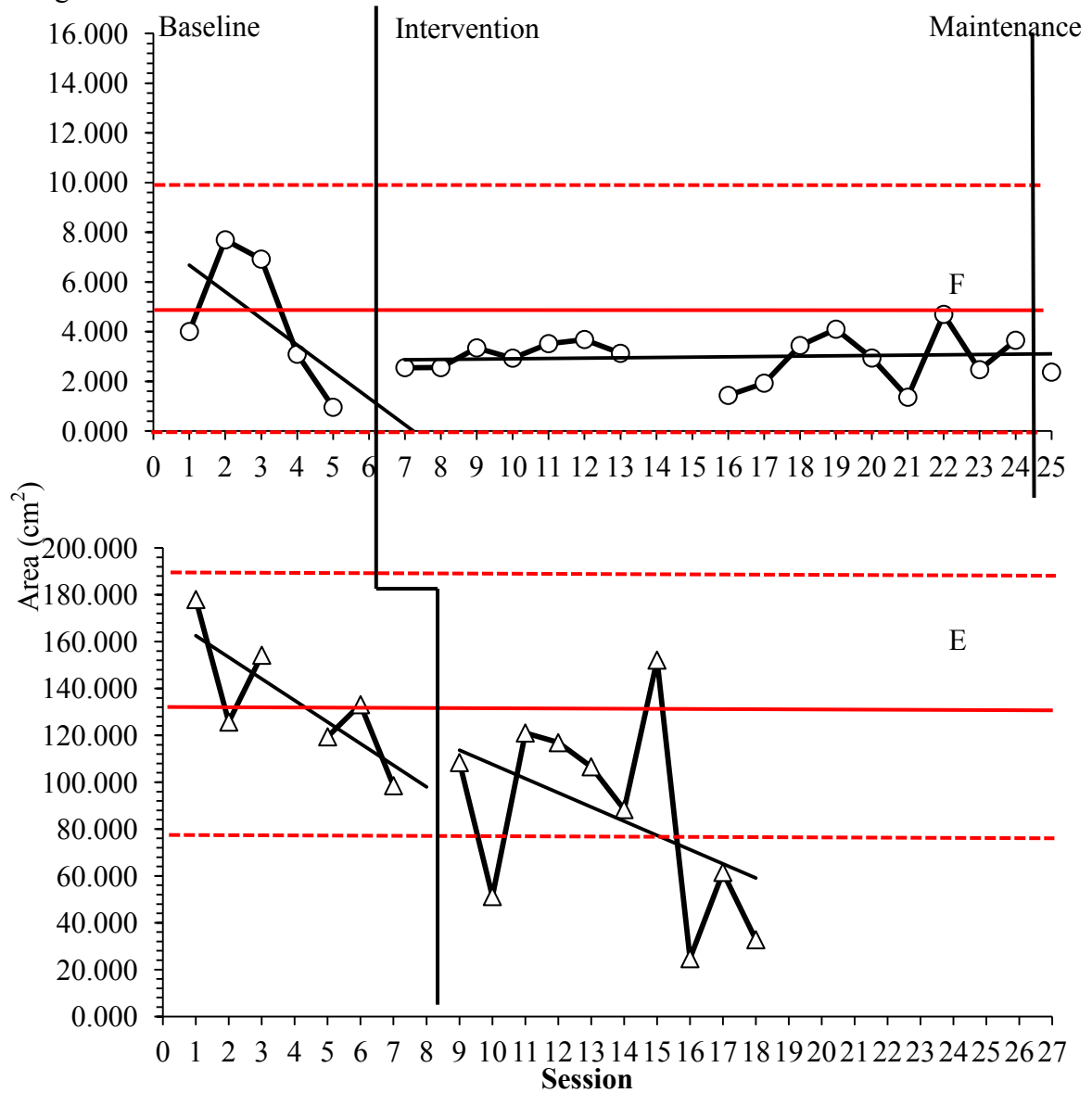


Figure 4.7 continued



Note. Participant E y-axis greater than all other participants.



Figure 4.8

Center of Pressure Area with Eyes Closed

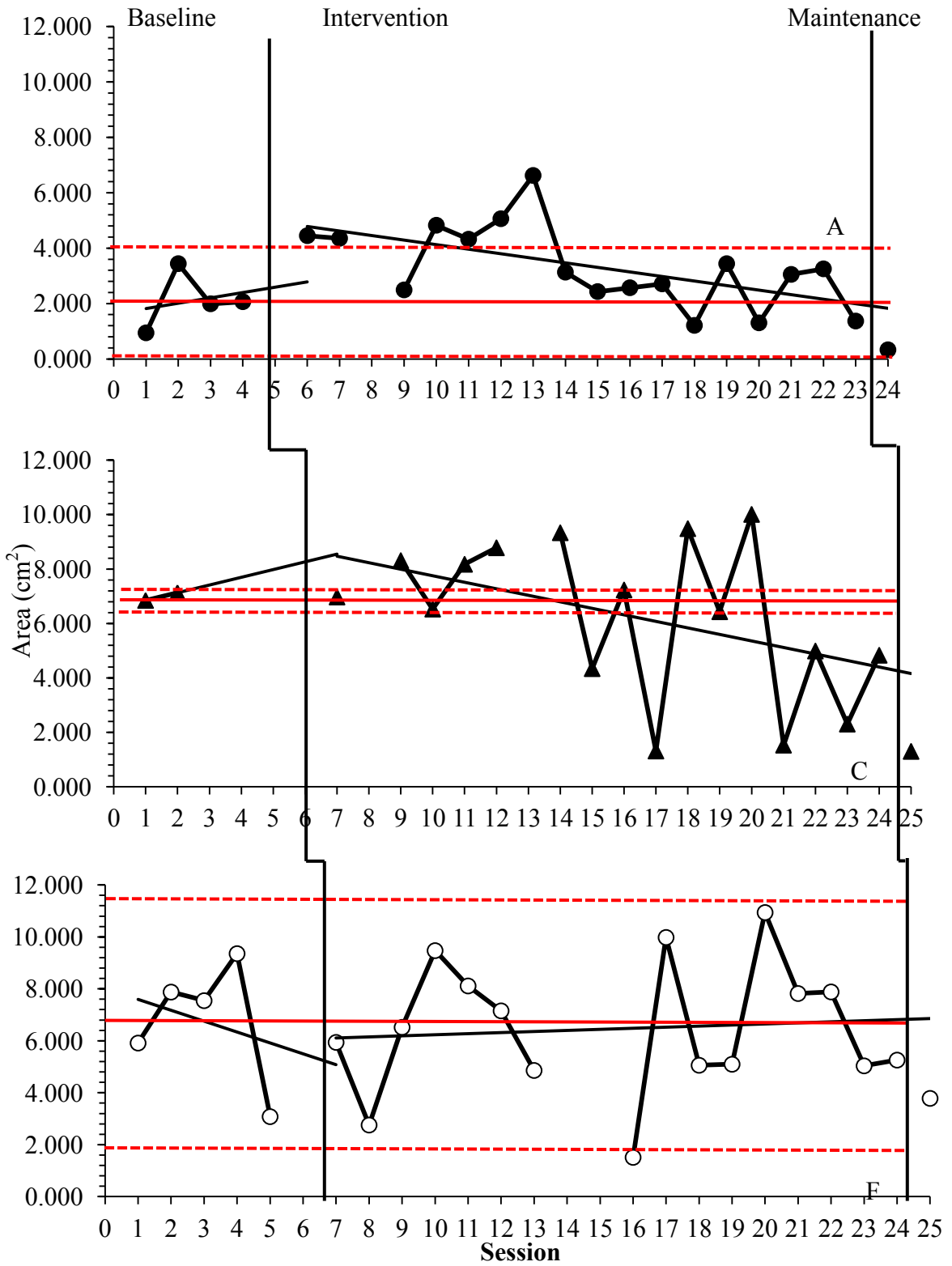


Figure 4.9

Center of Pressure Velocity with Eyes Open

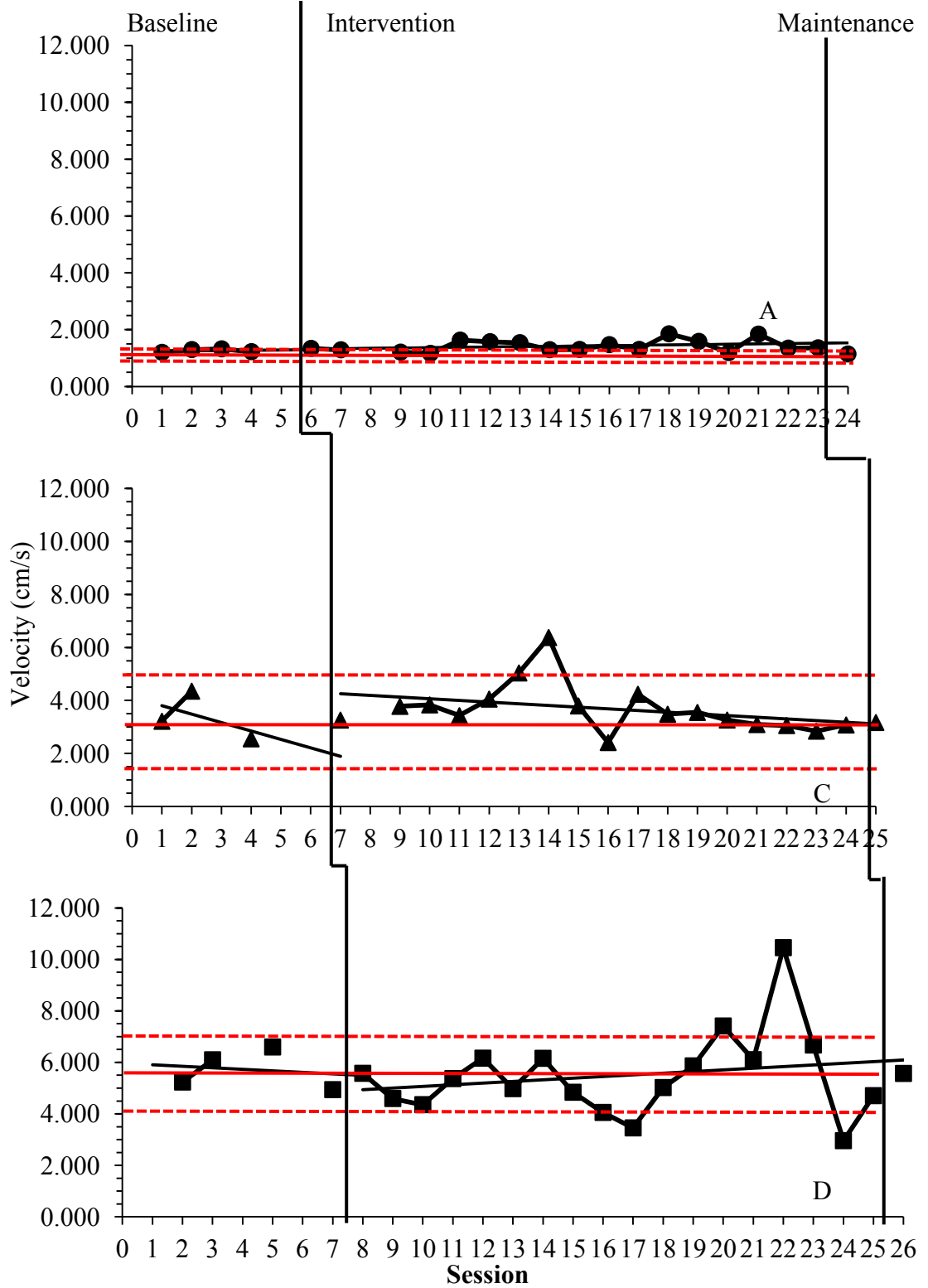
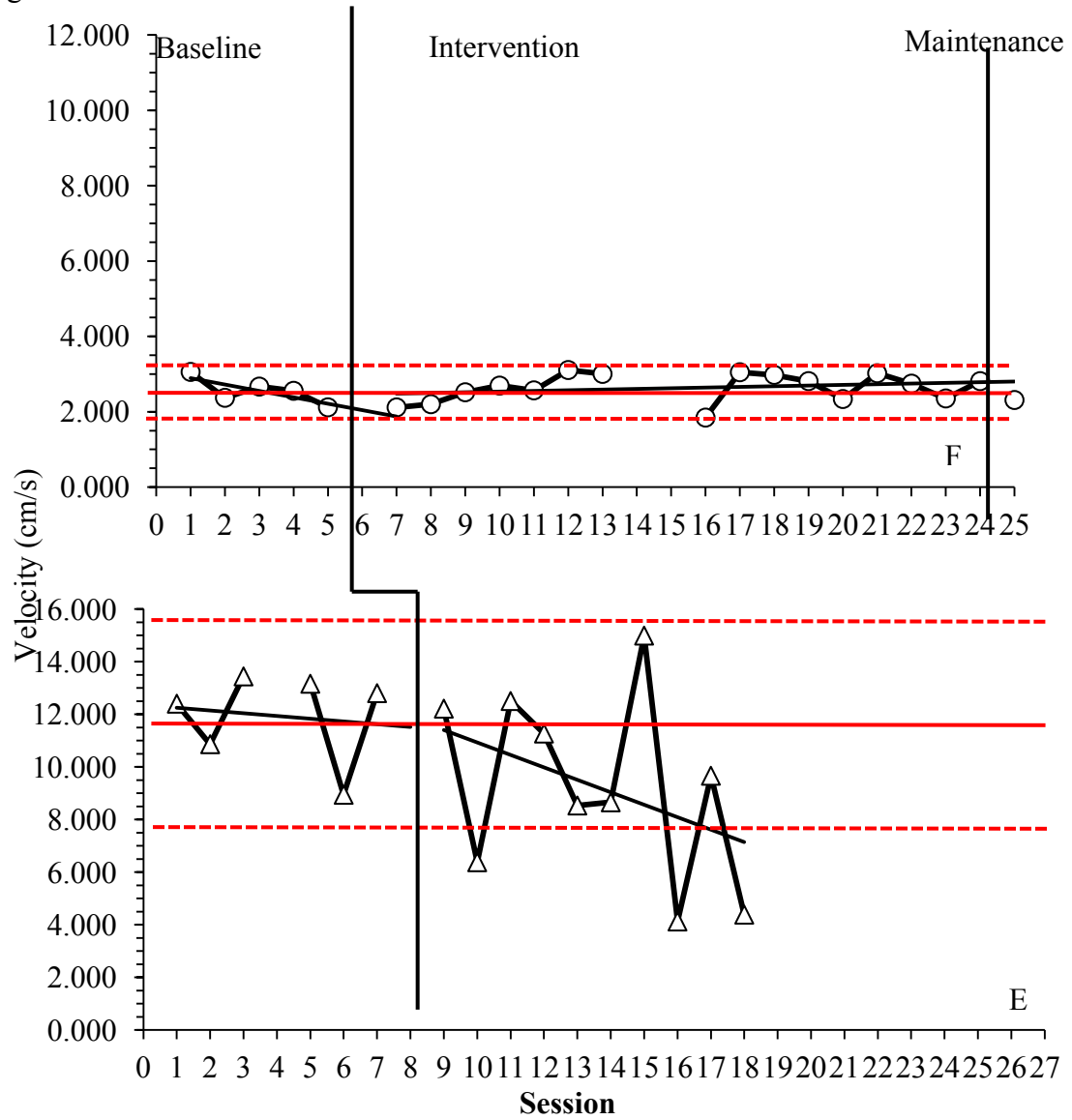


Figure 4.9 continued



Note. Participant E has a larger y axis.

Figure 4.10

*Center of Pressure Velocity with Eyes Closed*

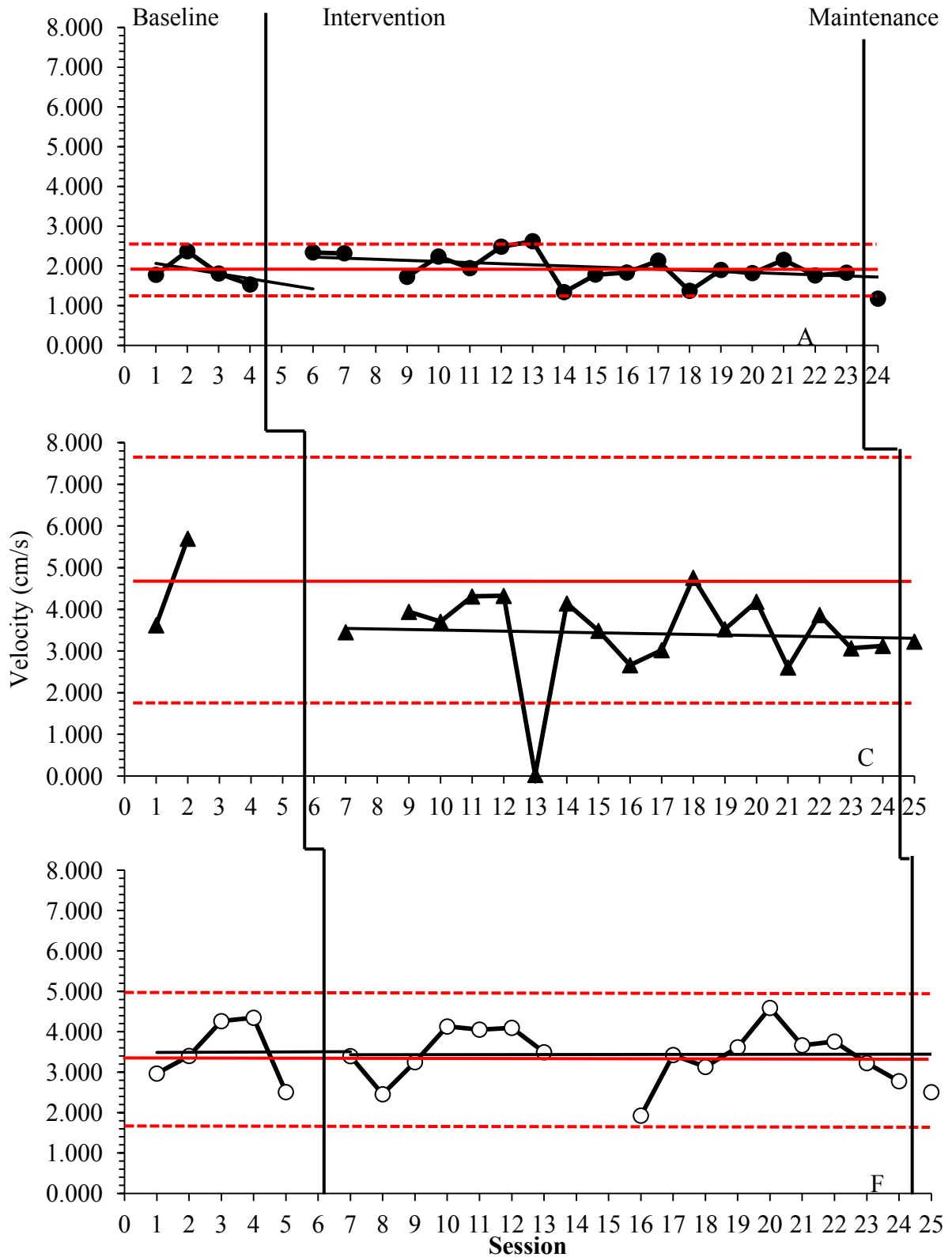


Figure 4.11

*Time to Boundary Mean Minima in Anterior-Posterior direction with Eyes Open*

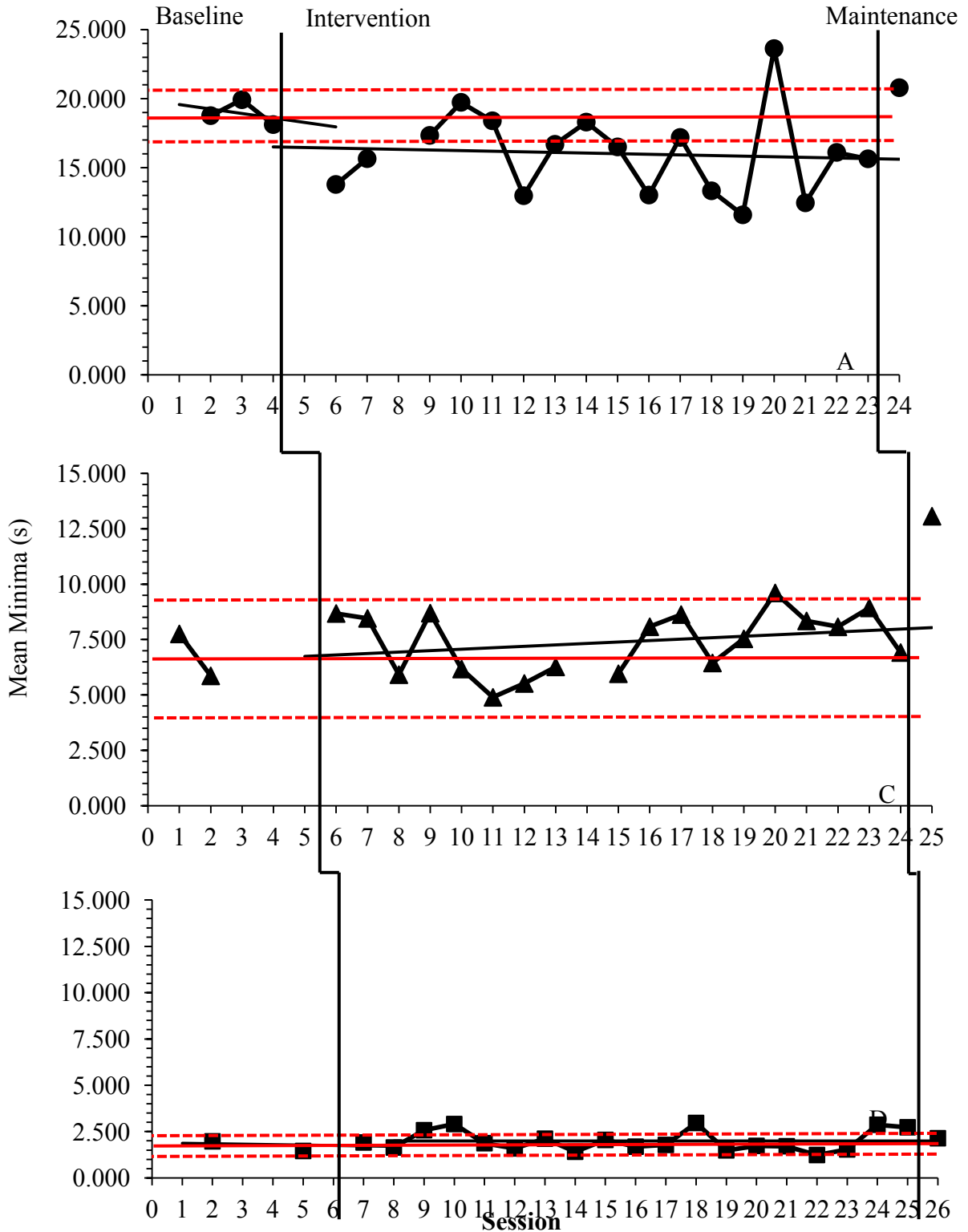
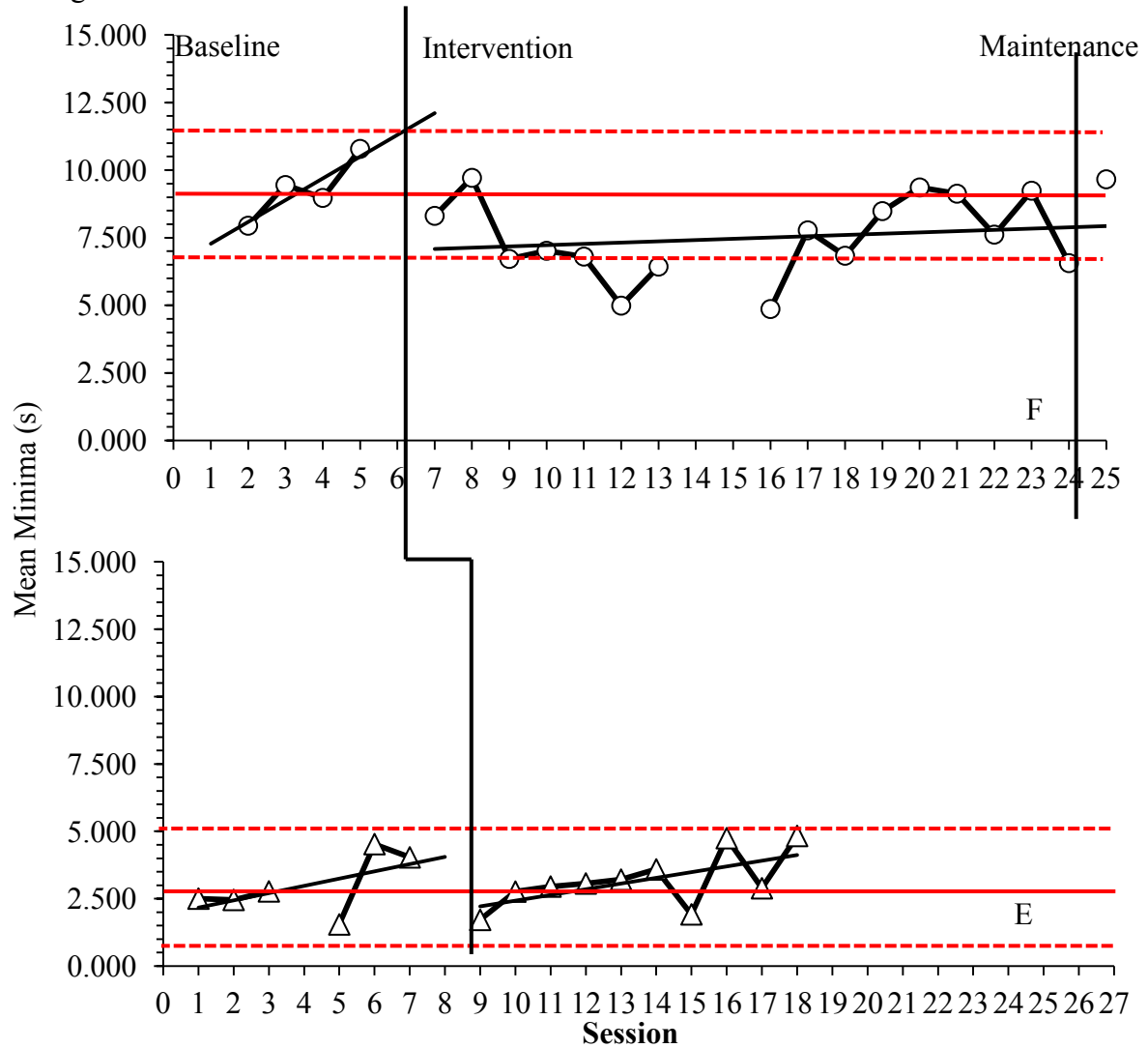


Figure 4.11 continued



Note. Participant A has a larger y-axis.

Figure 4.12

*Time to Boundary Mean Minima in Anterior-Posterior direction with Eyes Closed*

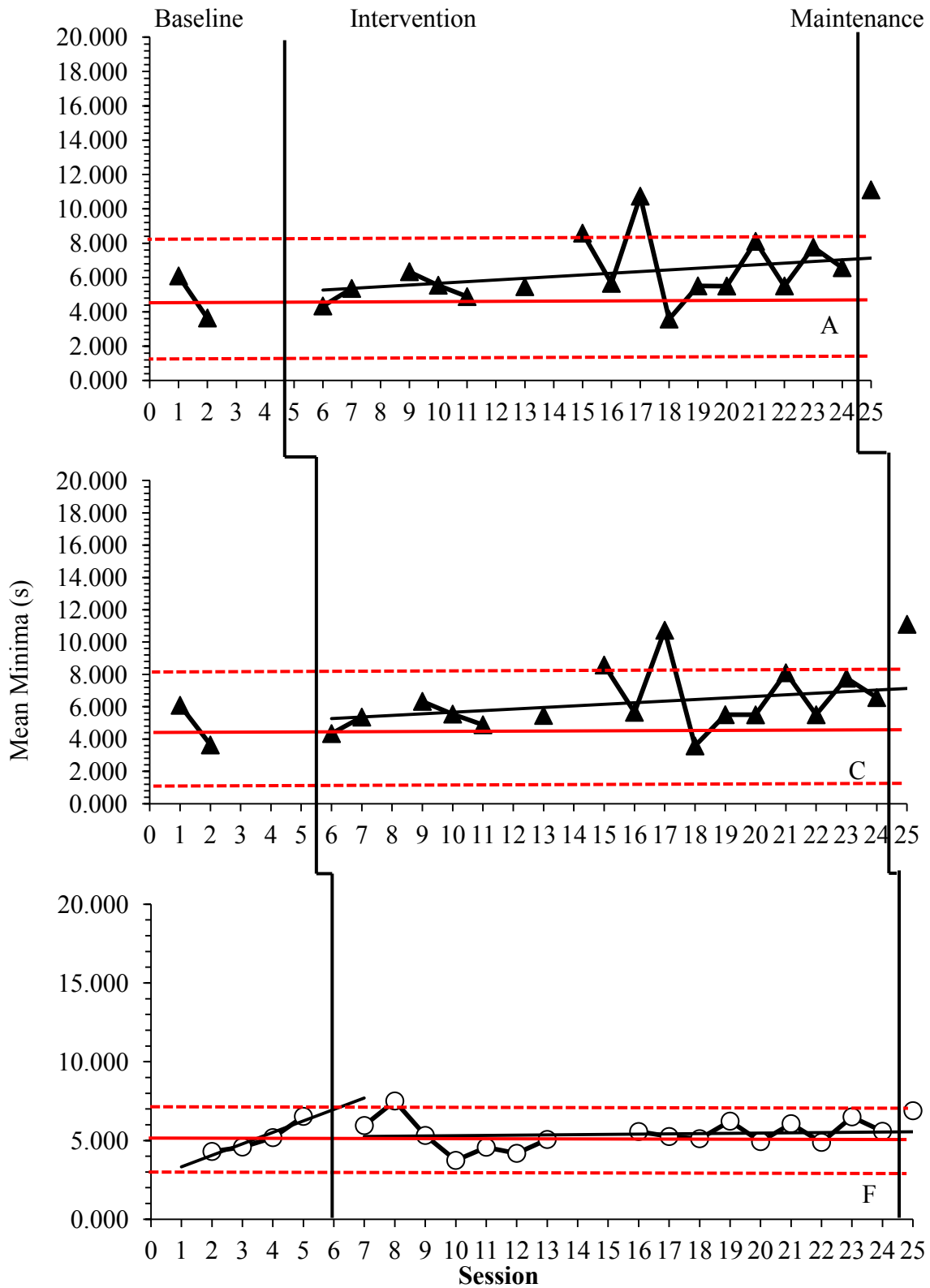


Figure 4.13

*Time to Boundary Mean Minima in Medial-Lateral direction with Eyes Open*

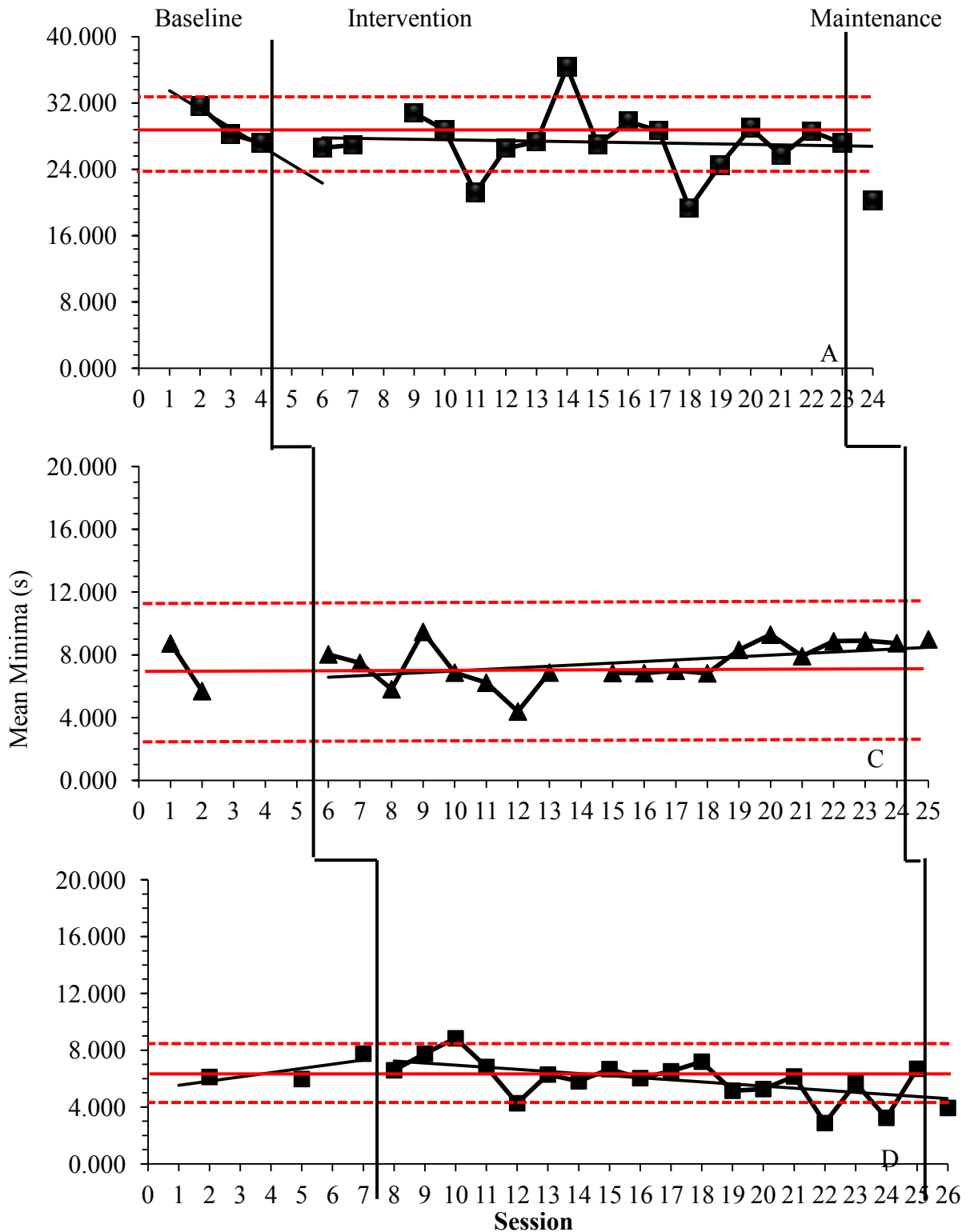
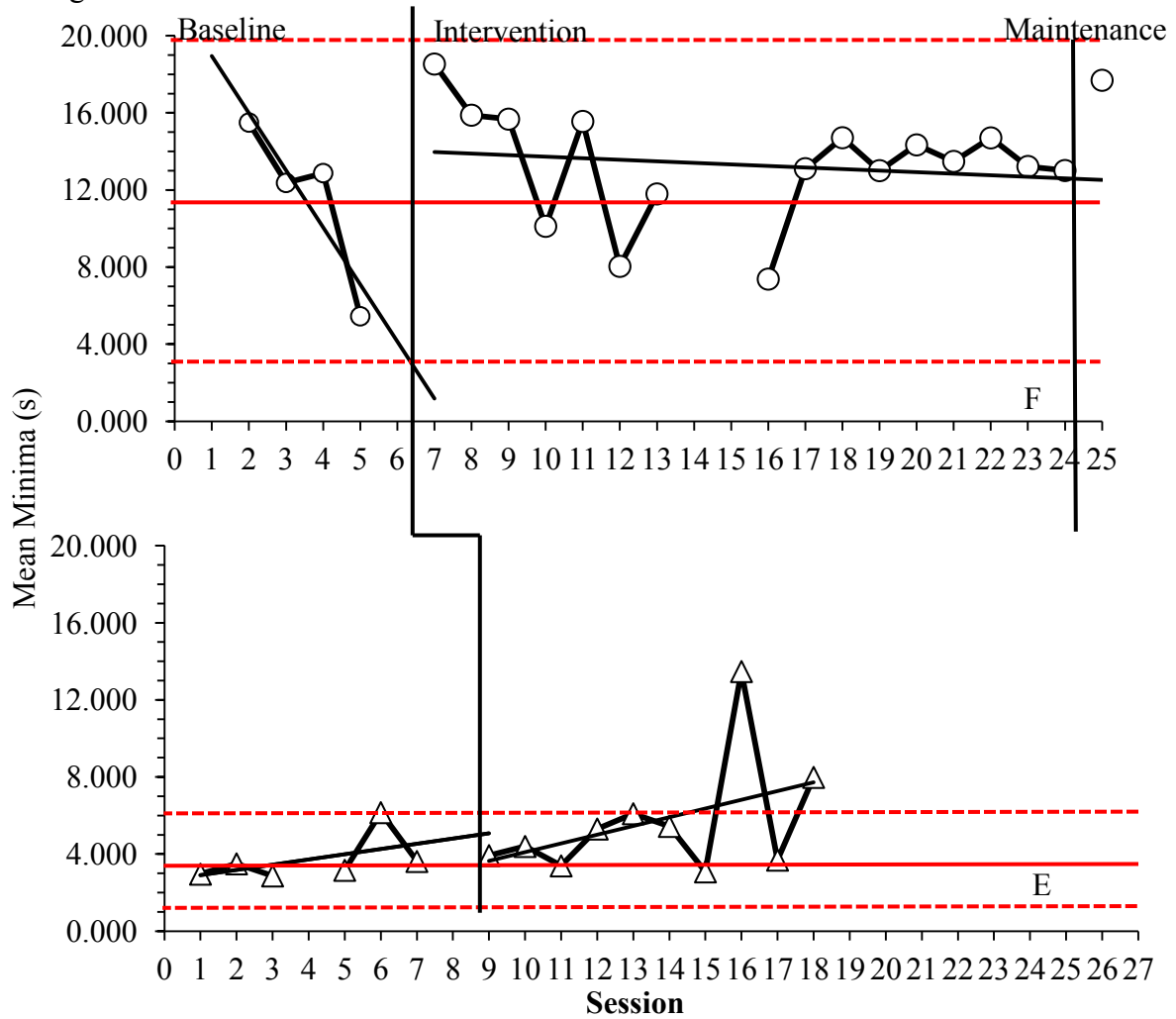




Figure 4.13 continued



Note. The y-axis of Participant A is larger.

Figure 4.14

*Time to Boundary Mean Minima in Medial-Lateral direction with Eyes Closed*

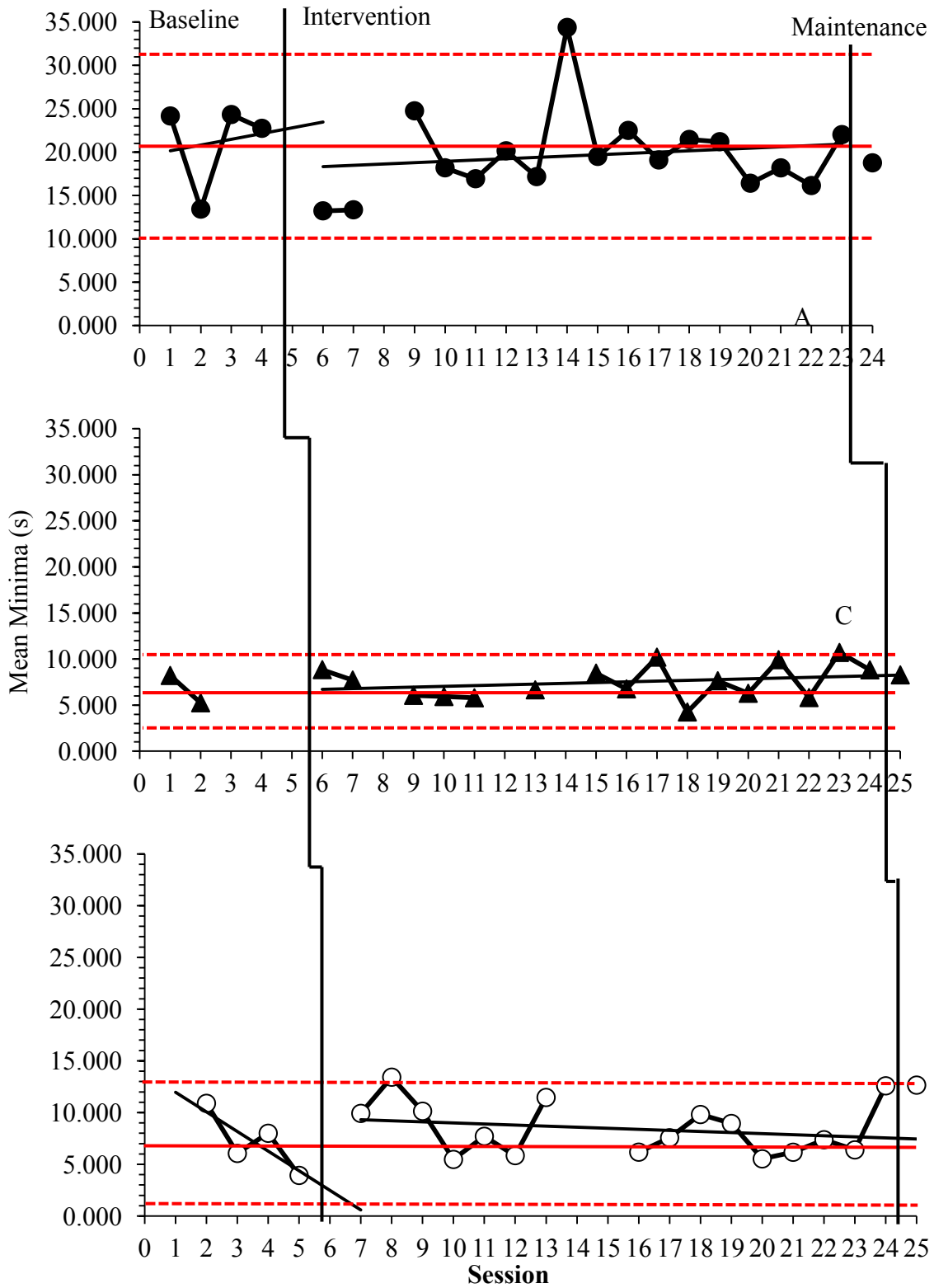


Figure 4.15

*Time to Boundary Standard Deviation in Anterior-Posterior direction with Eyes Open*

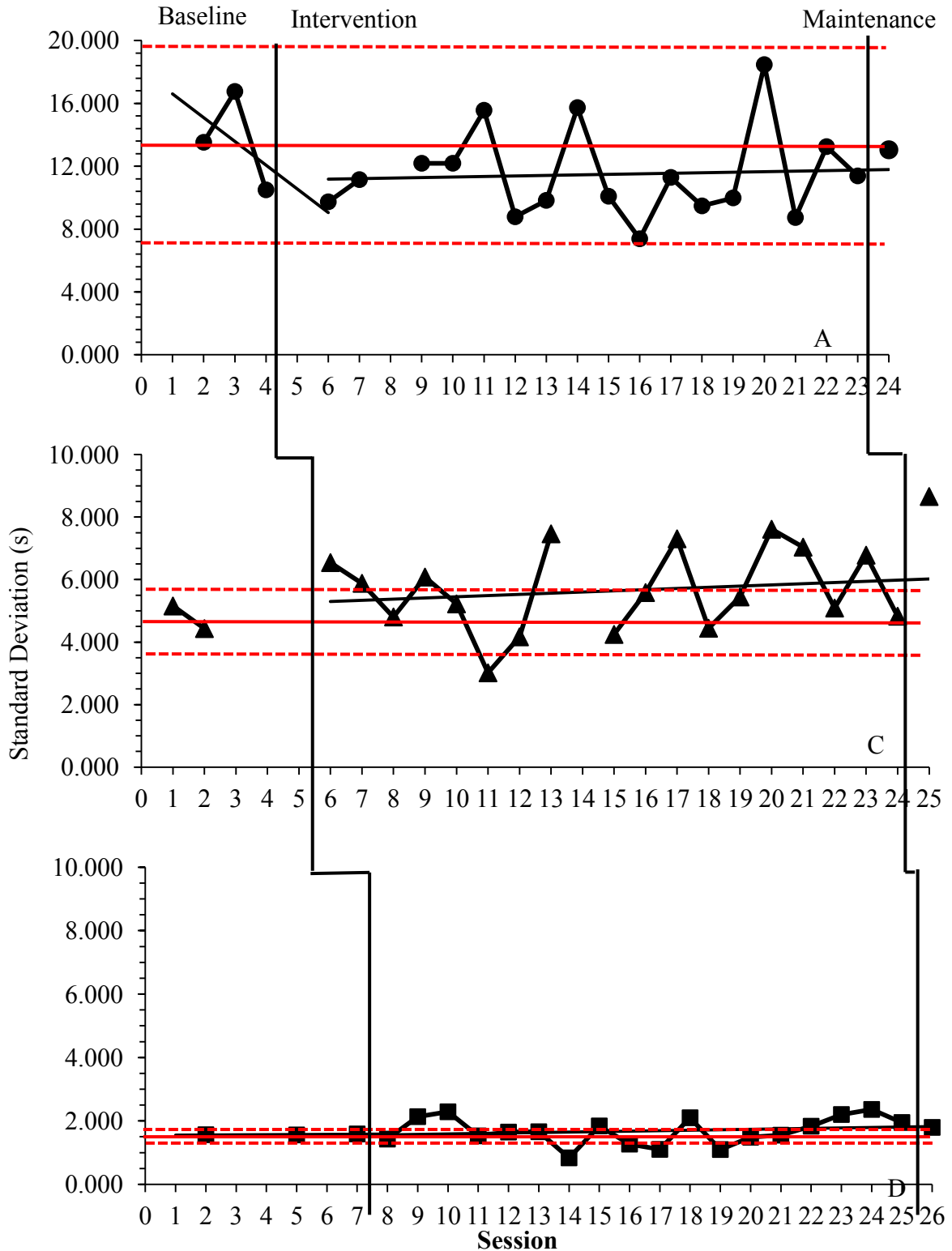
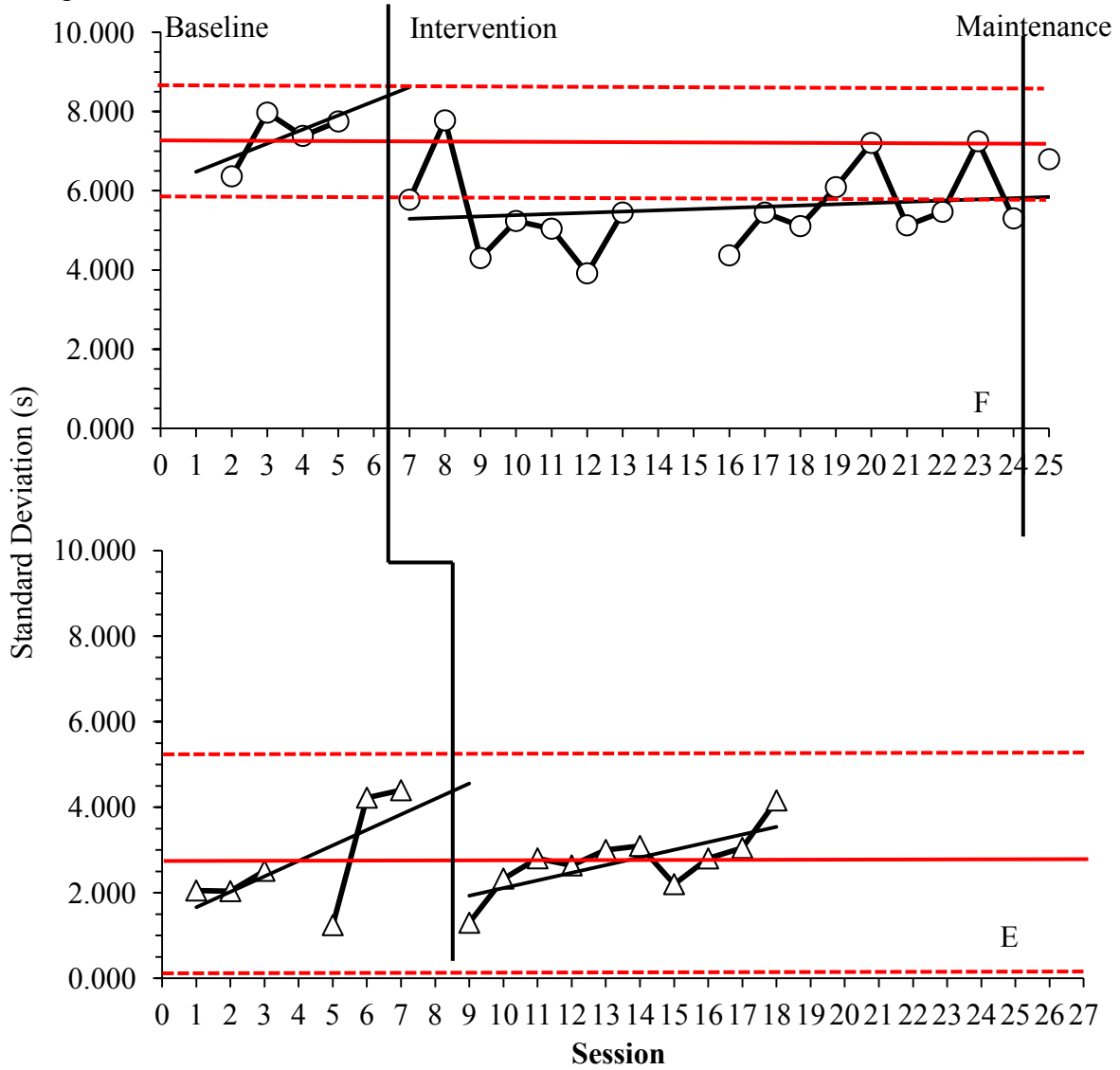


Figure 4.15 continued



Note. Participant A has a larger y-axis

Figure 4.16

*Time to Boundary Standard Deviation in Anterior Posterior Direction with Eyes Closed*

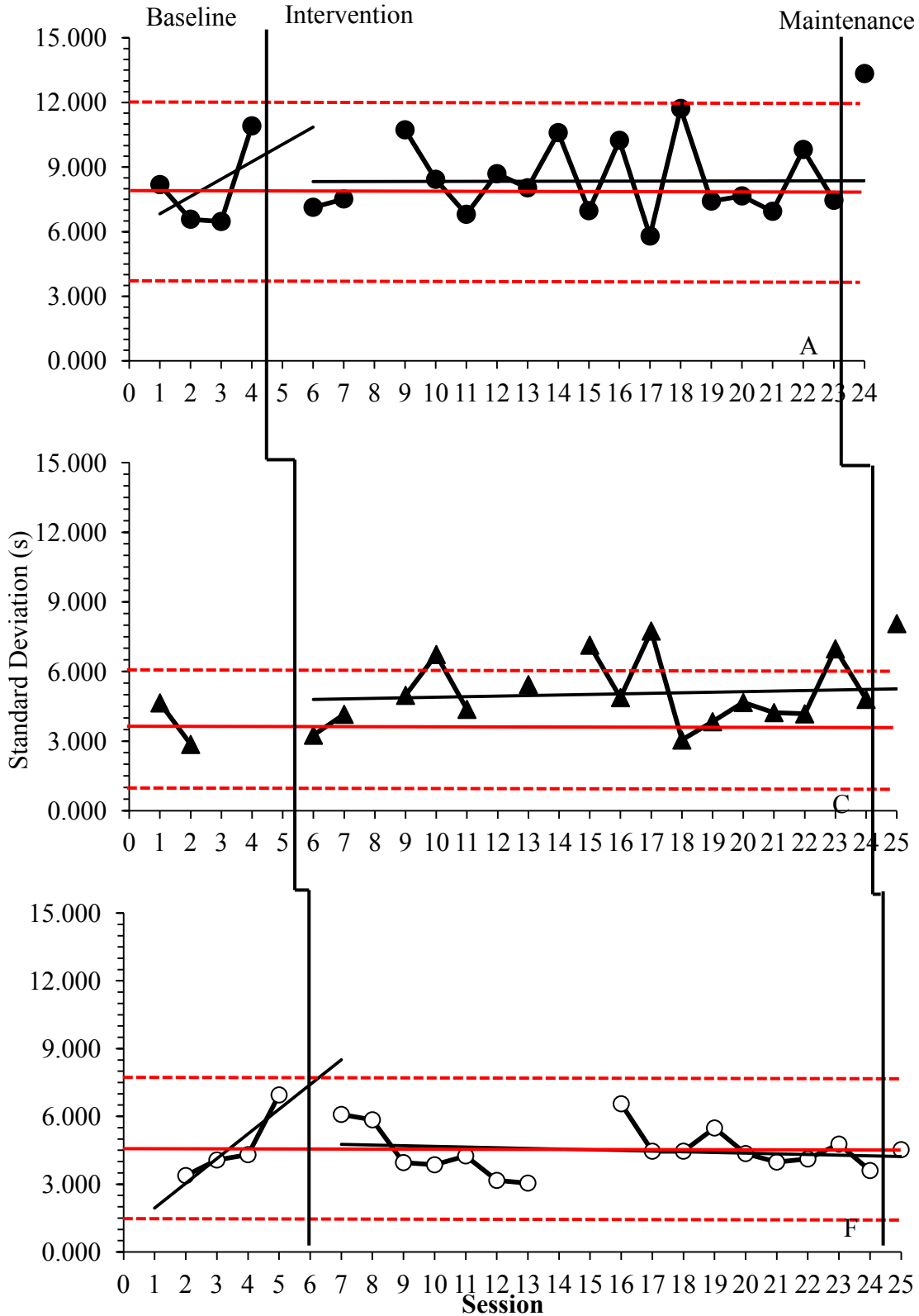


Figure 4.17

*Time to Boundary Standard Deviation Medial-Lateral direction with Eyes Open*

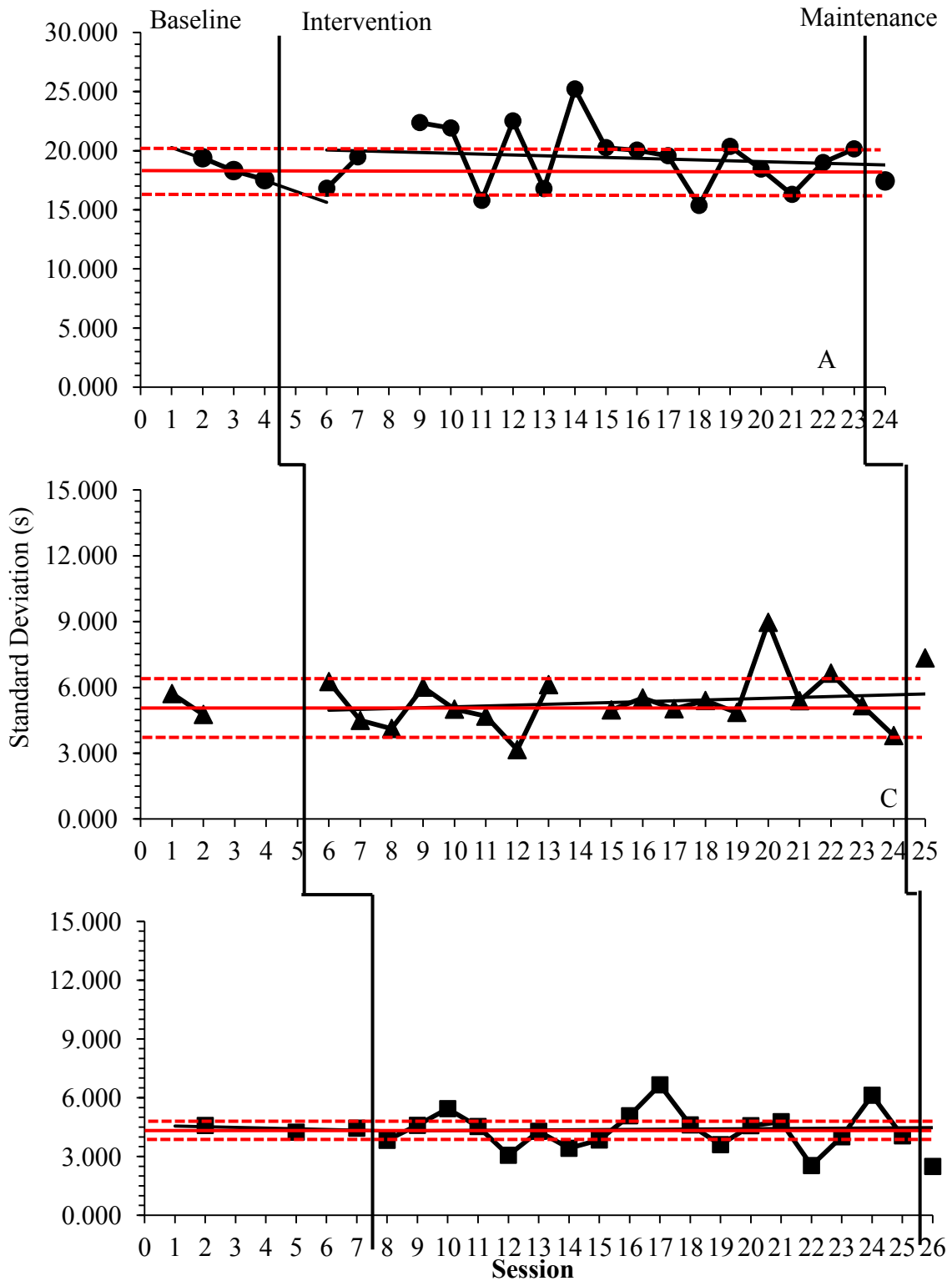
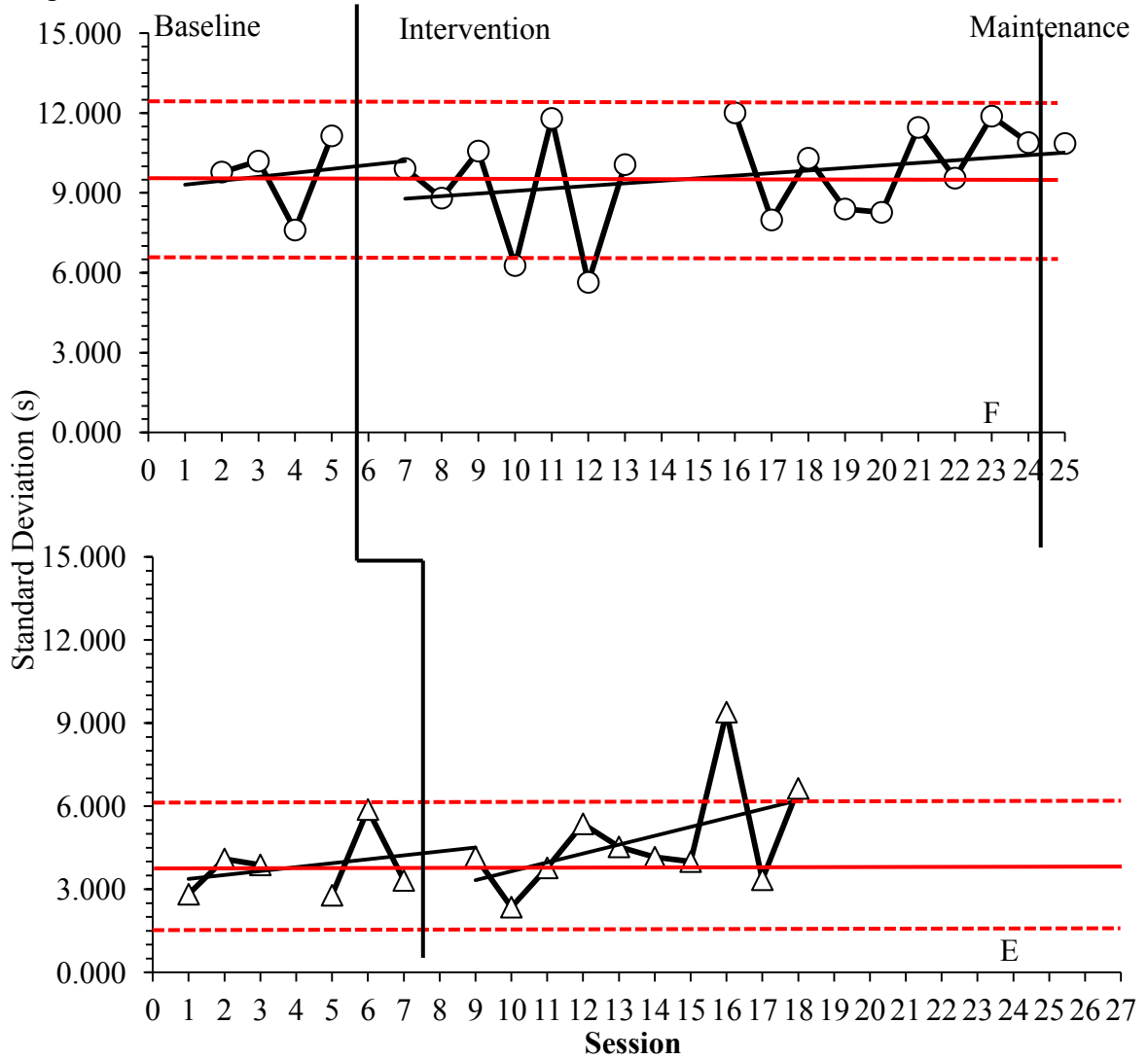


Figure 4.17 continued



Note. Participant A has a larger y-axis

Figure 4.18

*Time to Boundary Standard Deviation Medial Lateral Direction with Eyes Closed*

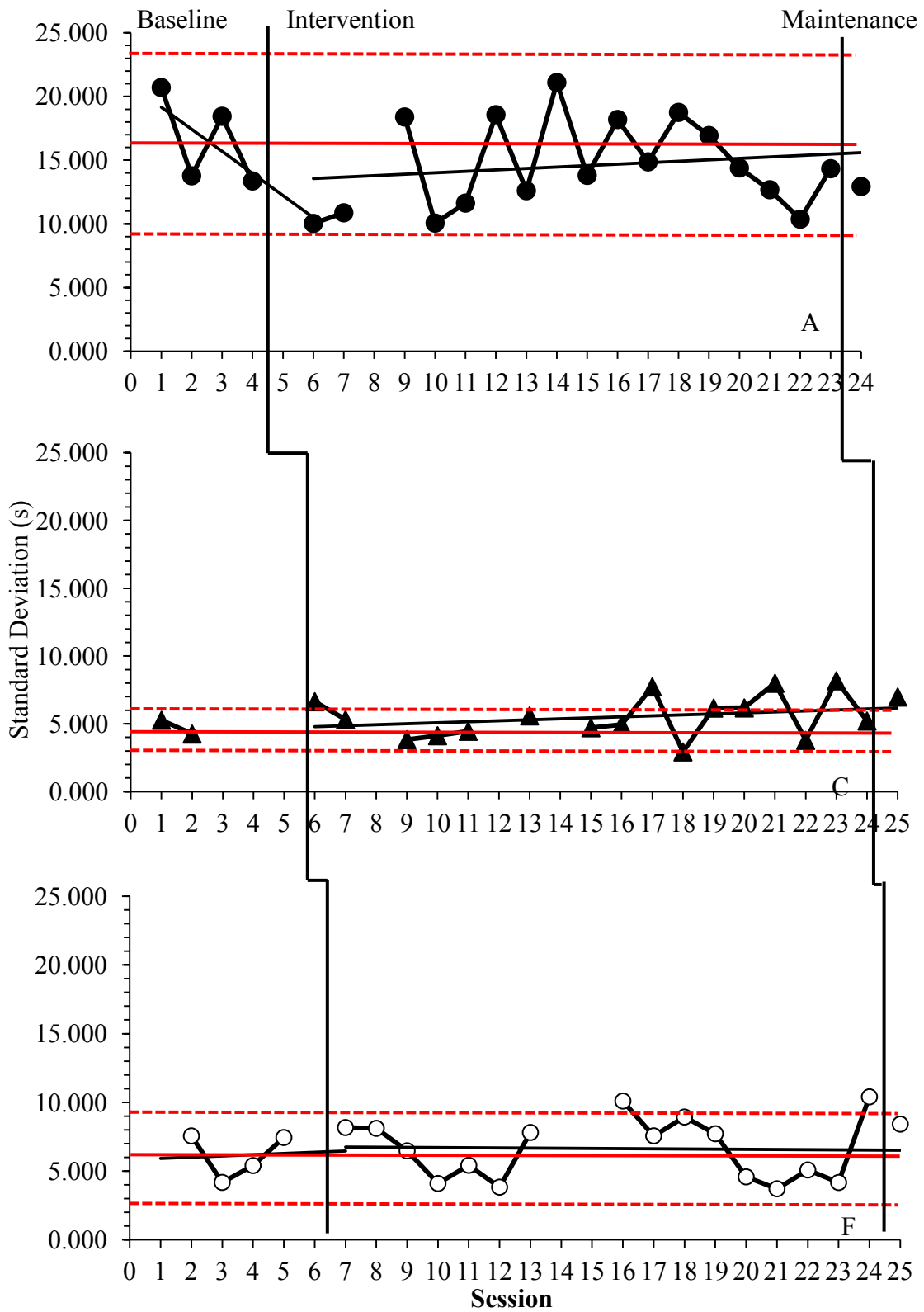




Figure 4.19

*Single Leg Stance Time*

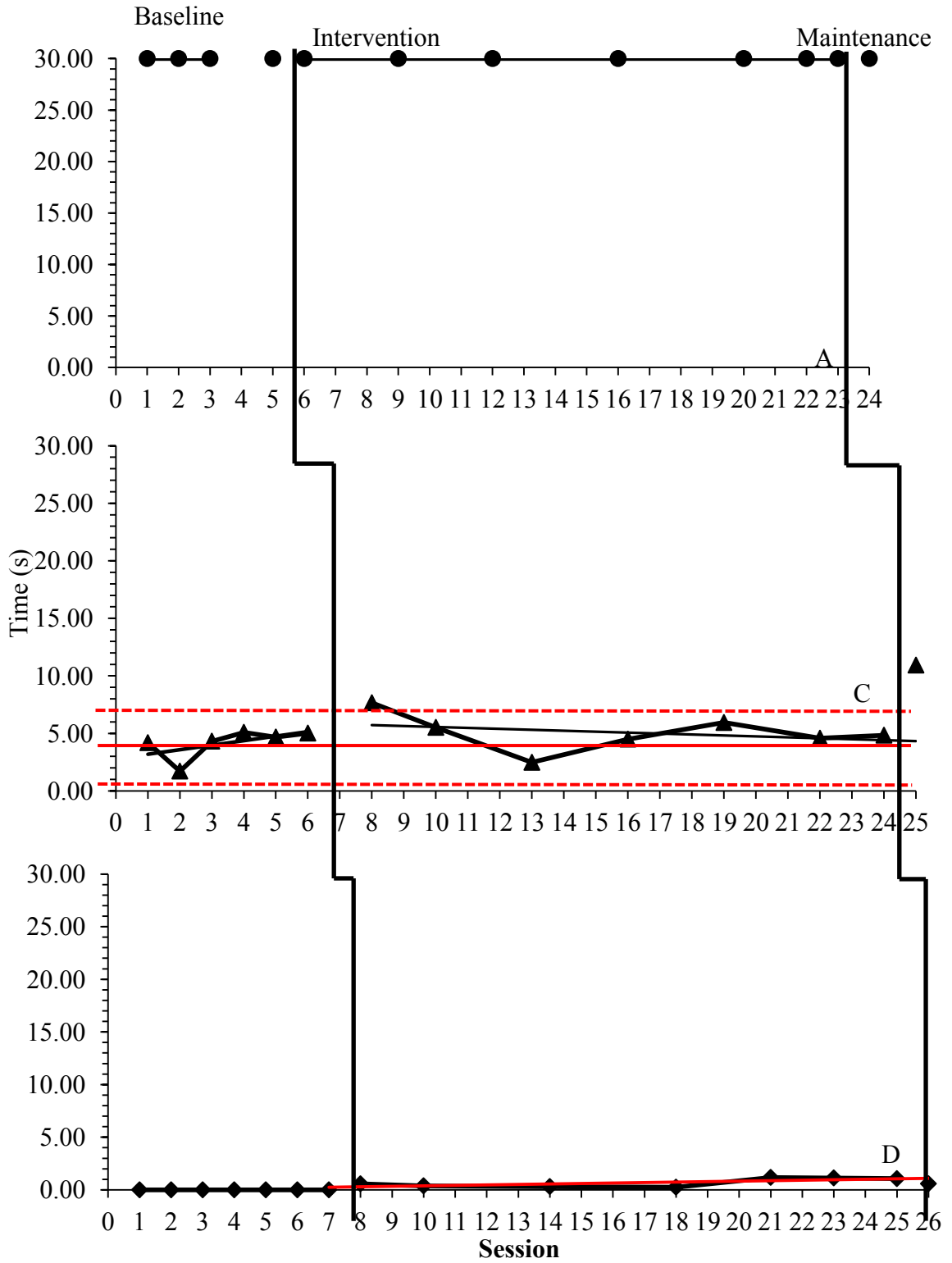


Figure 4.19 continued

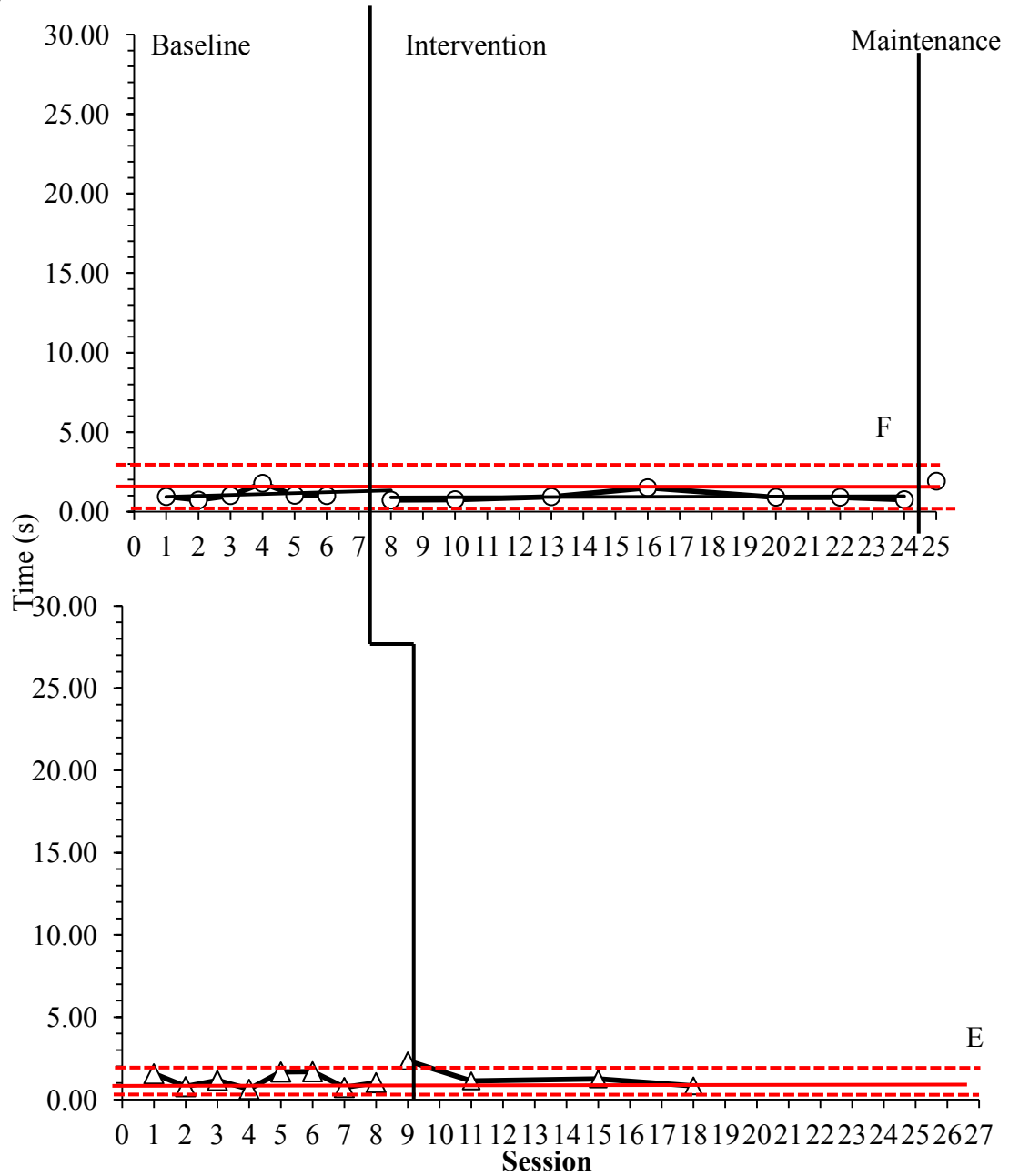


Figure 4.20

*Gait Velocity Results*

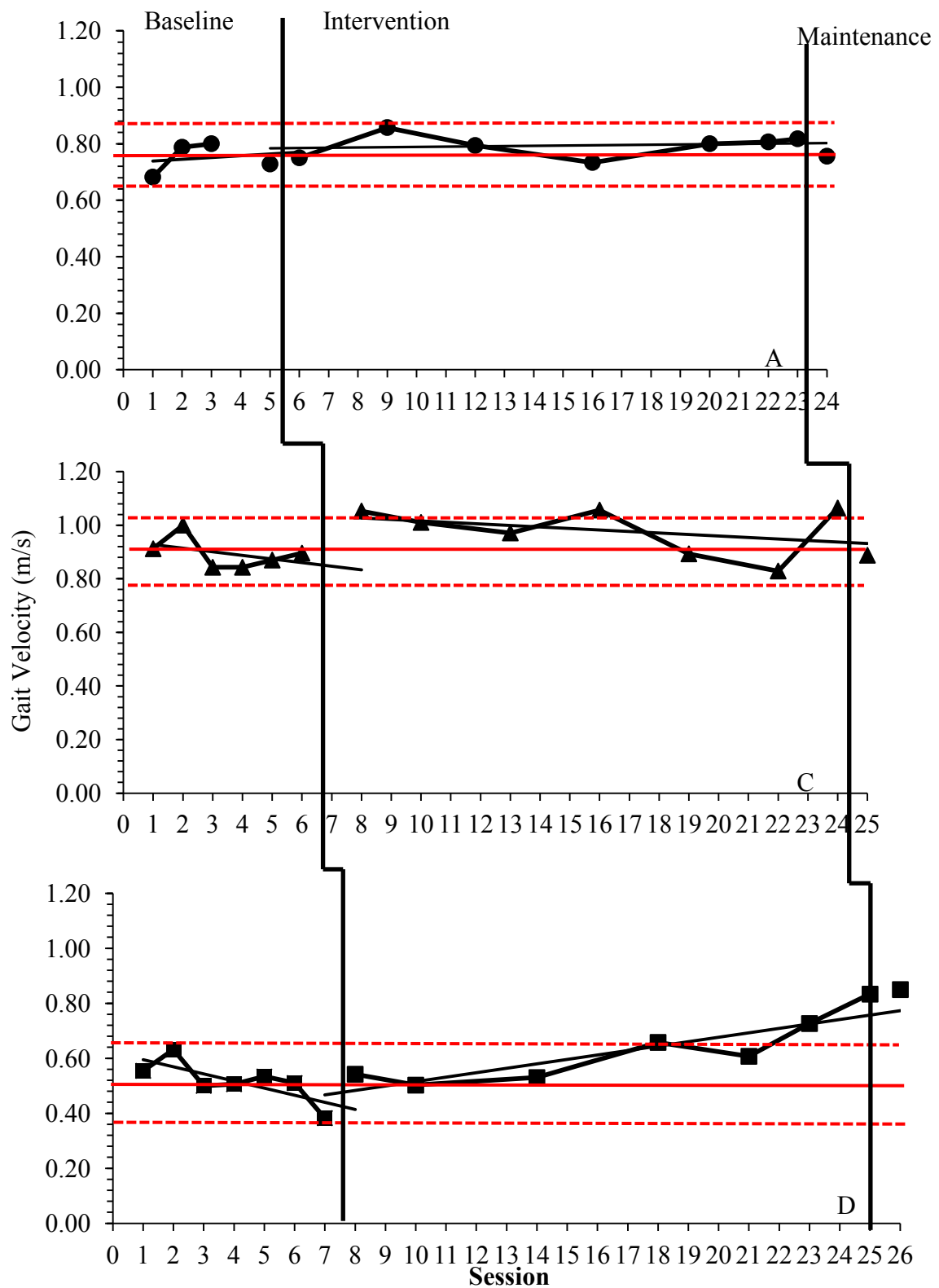


Figure 4.20 continued

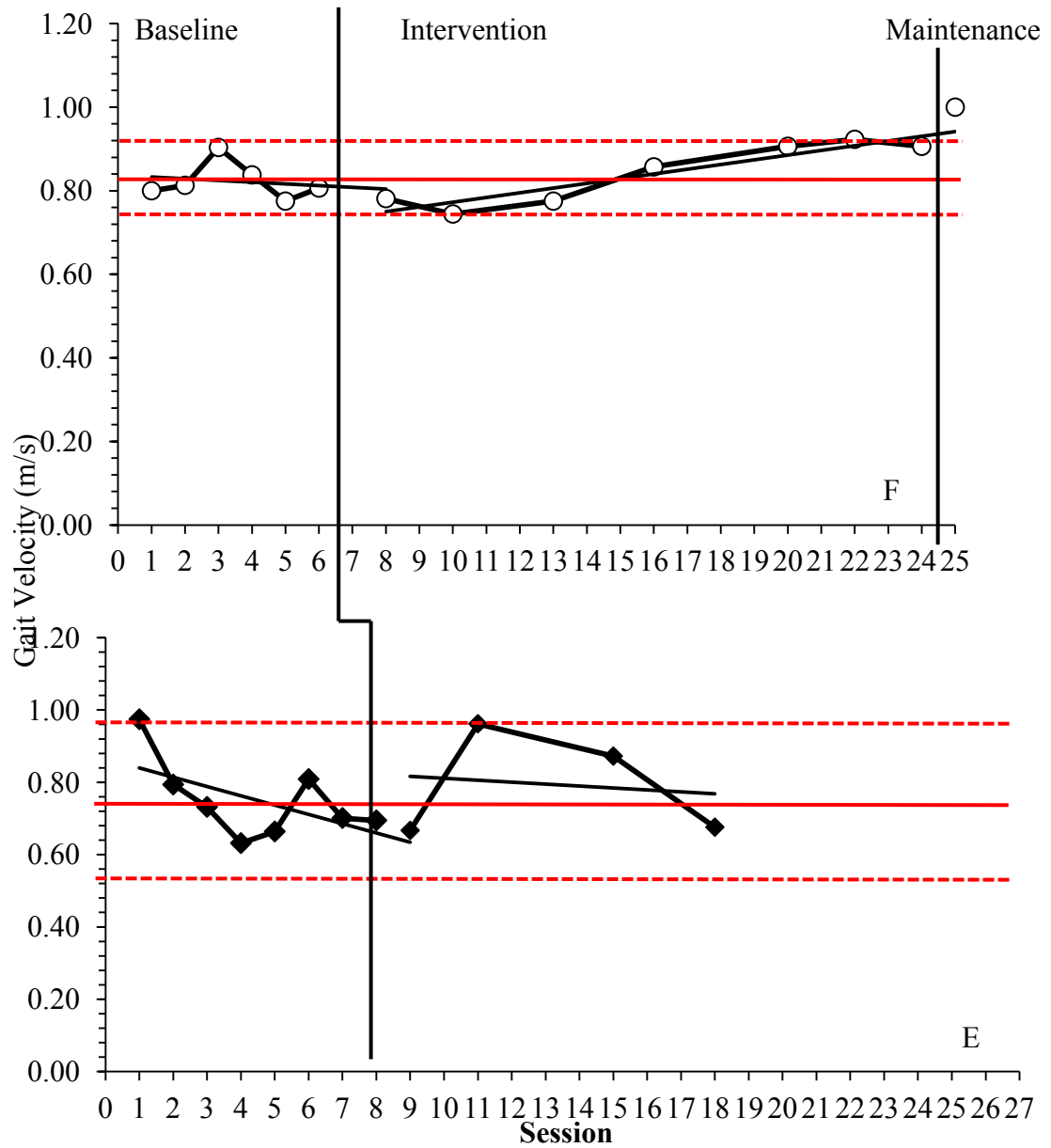


Figure 4.21

*Hip Abductor Strength Results*

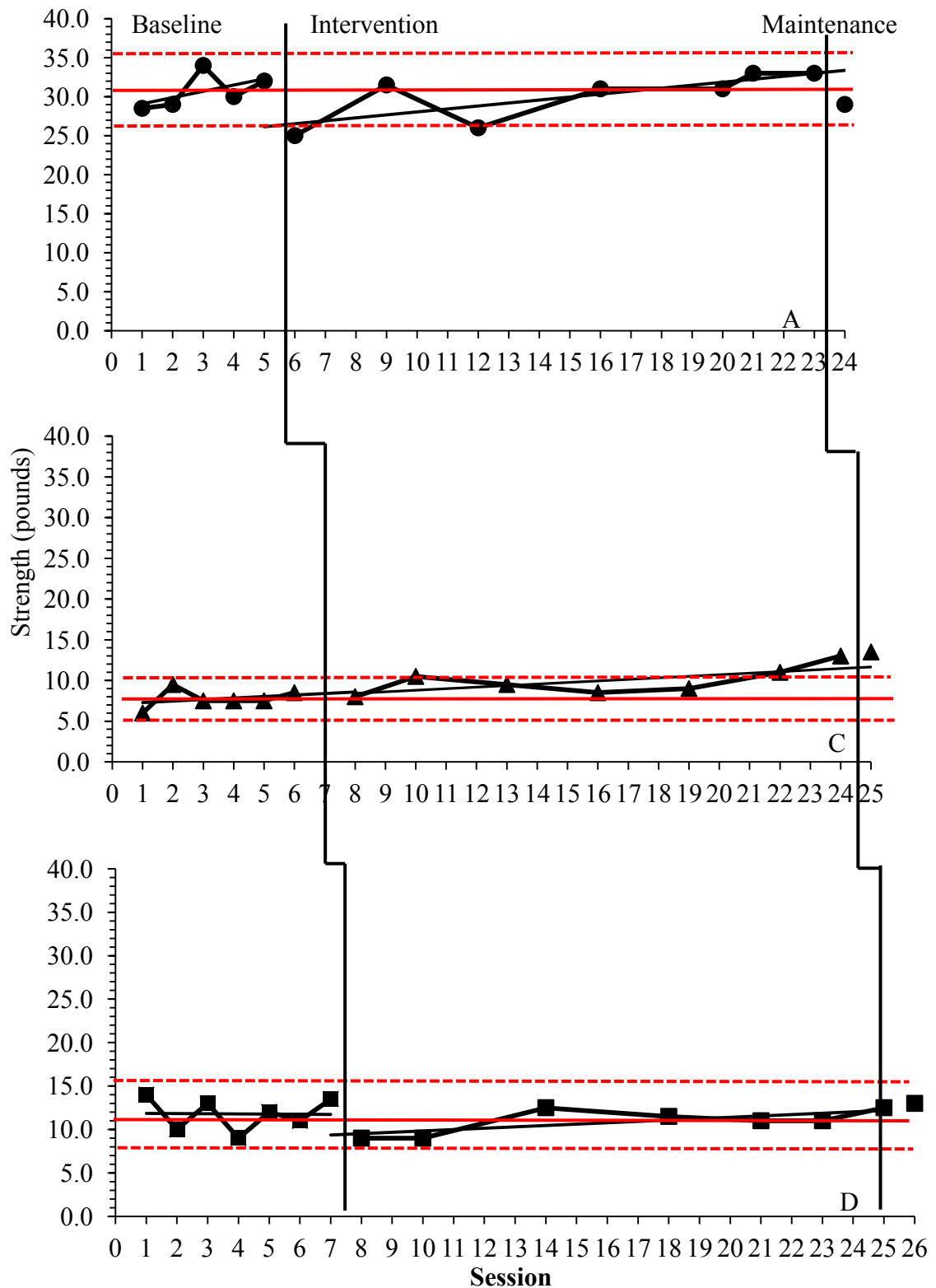


Figure 4.21 continued

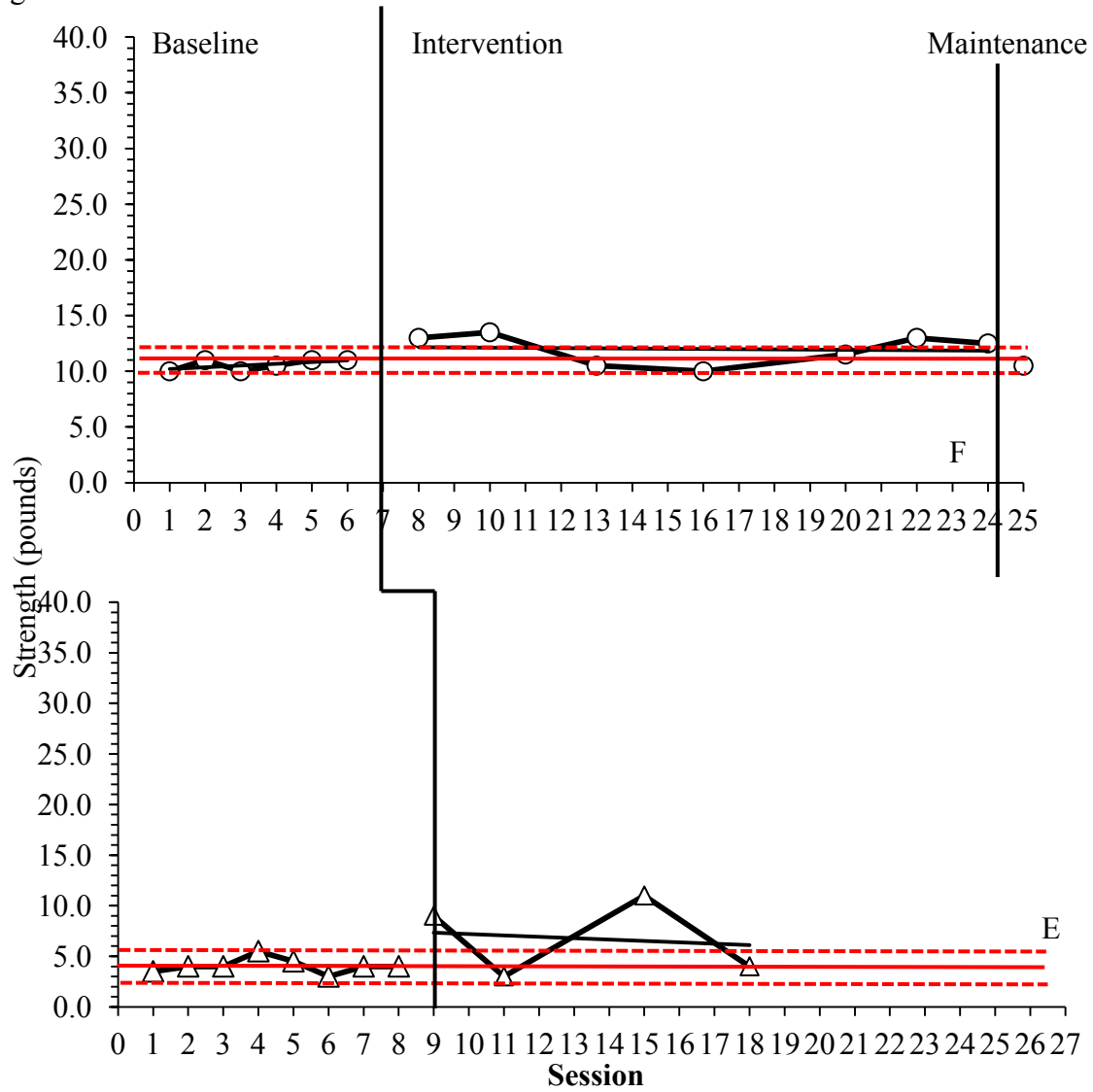


Figure 4.22

Activities Scale for Kids, performance version Results

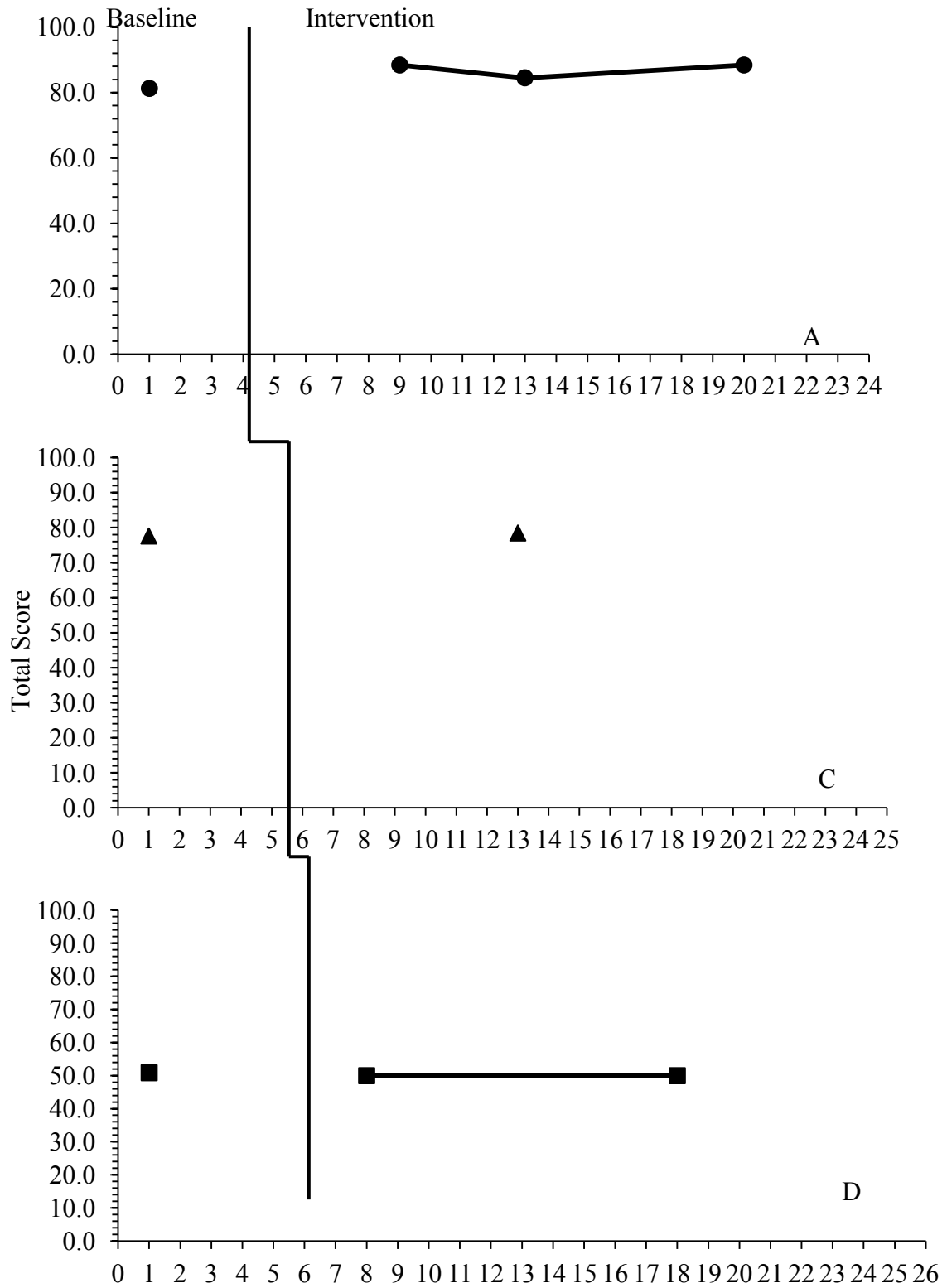


Figure 4.23

*Individual Enjoyment and Difficulty Questionnaire Results*

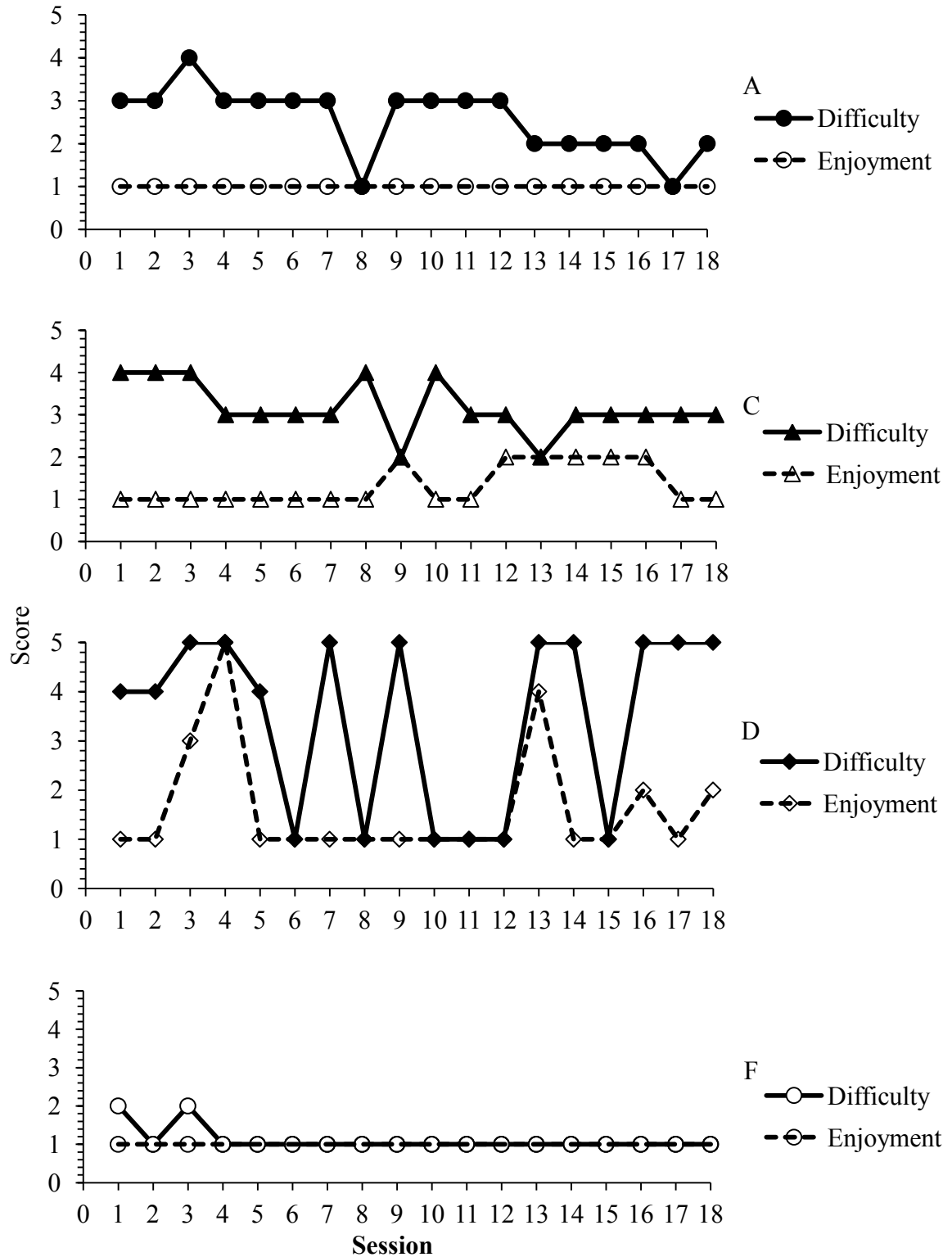




Figure 4.24

*Average Enjoyment and Difficult Questionnaire Results*

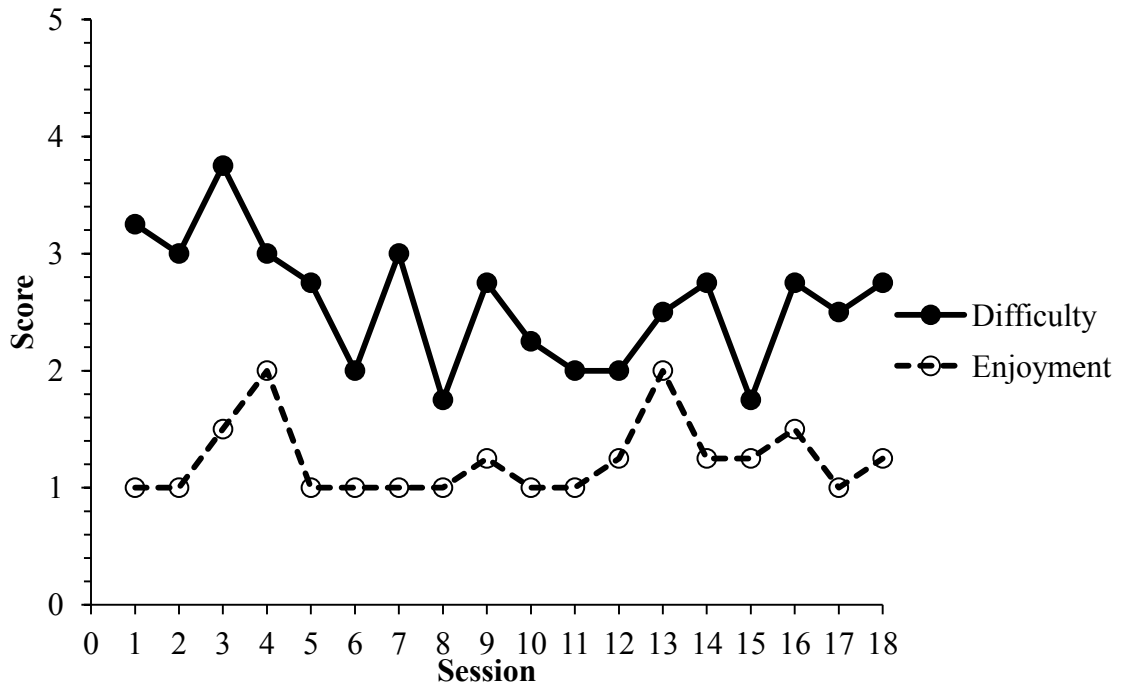


Figure 4.25

*Individual Penguin Slide Results*

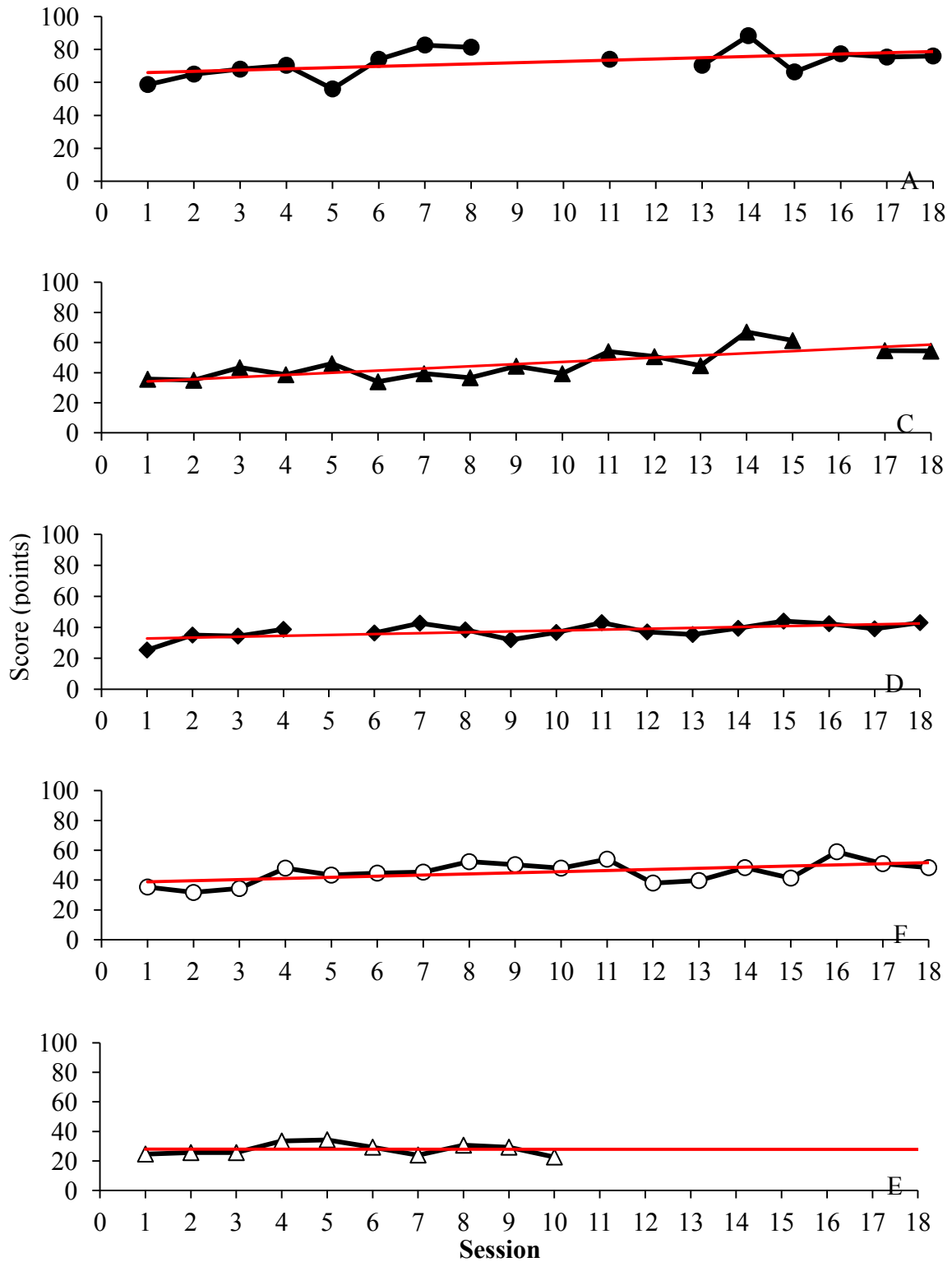


Figure 4.26

*Individual Soccer Heading Results*

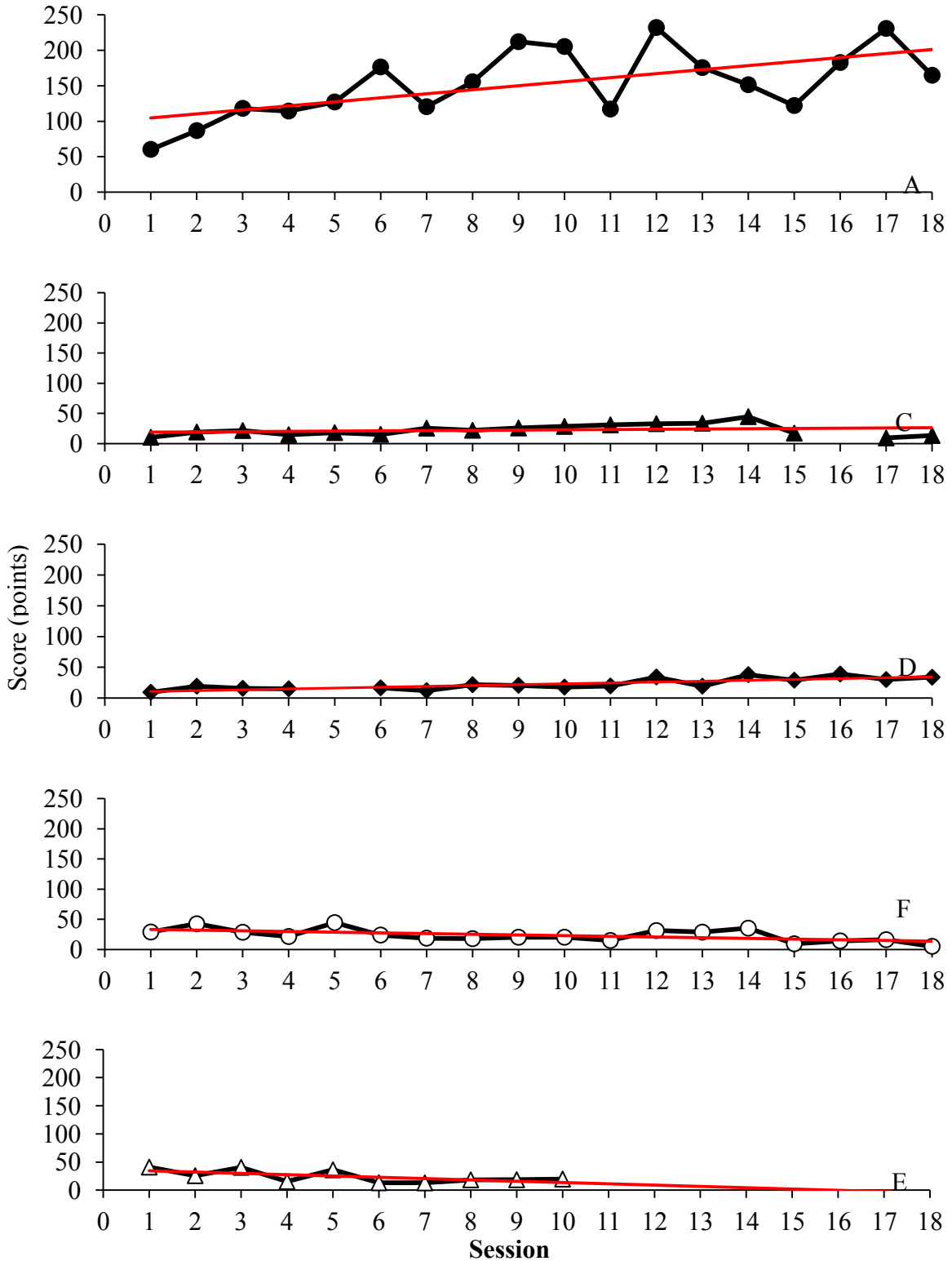


Figure 4.27

*Individual Ski Slalom Results*

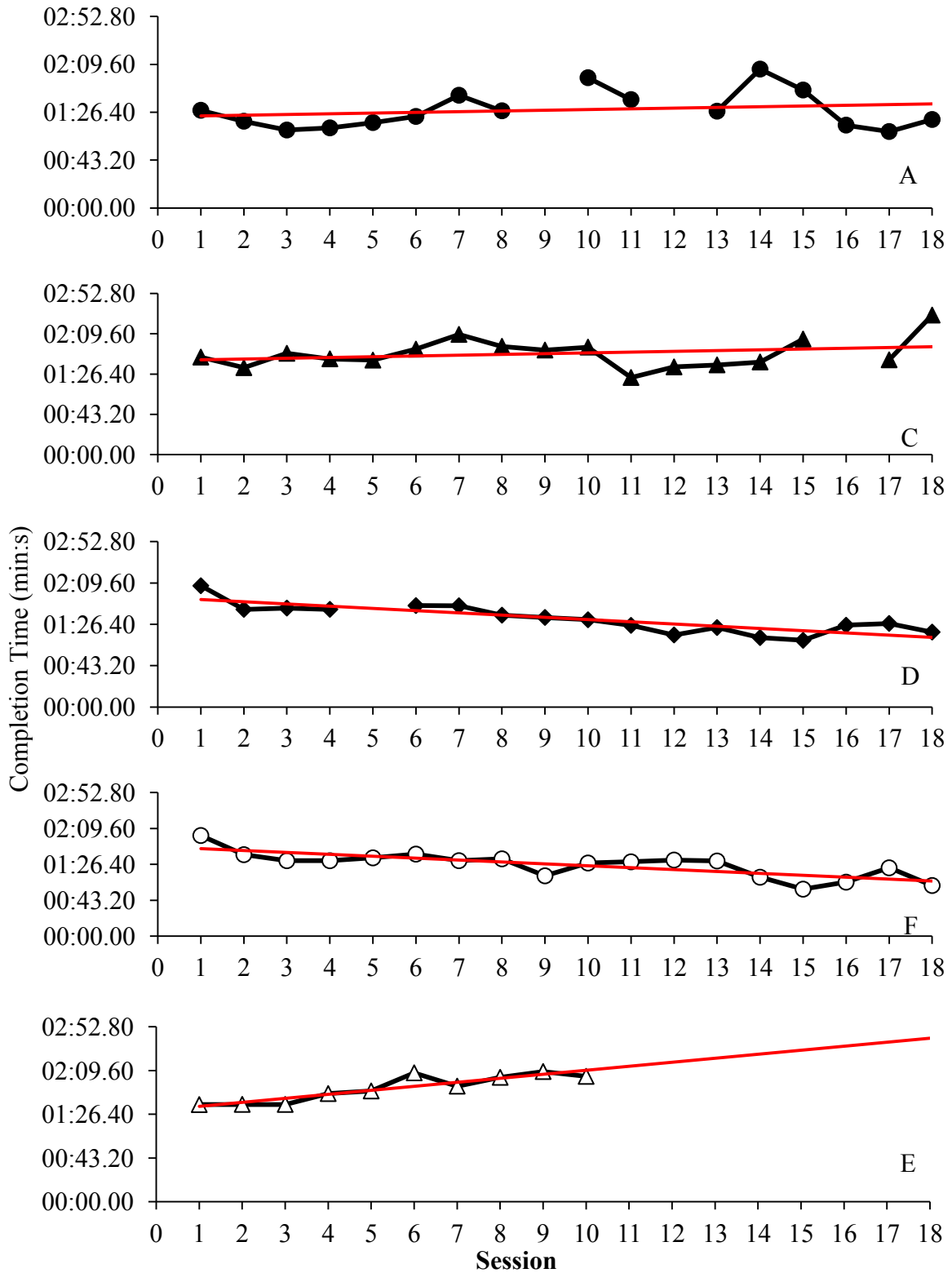


Figure 4.28

*Individual Balance Bubble Results*

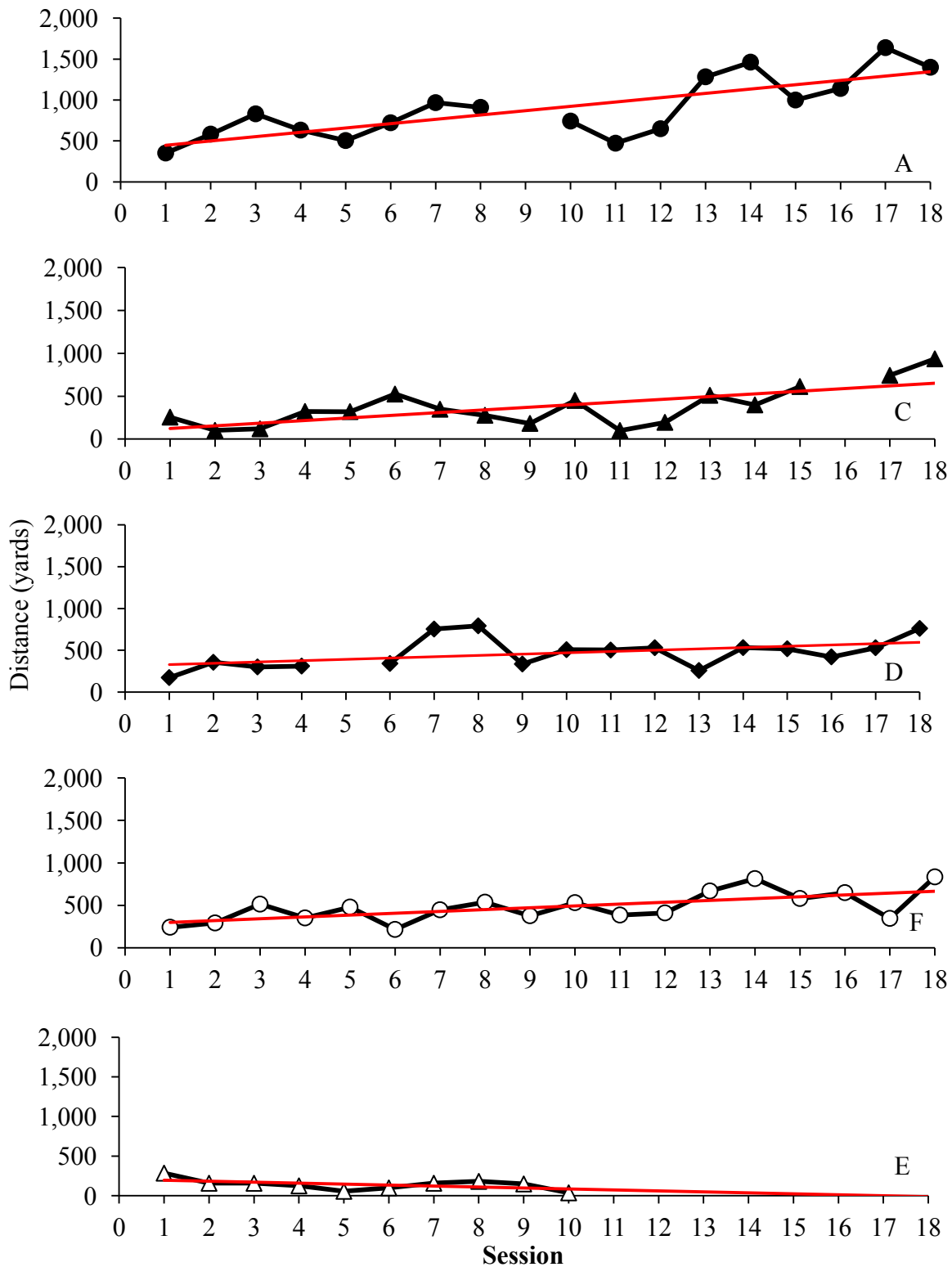


Figure 4.29

*Individual Table Tilt Results*

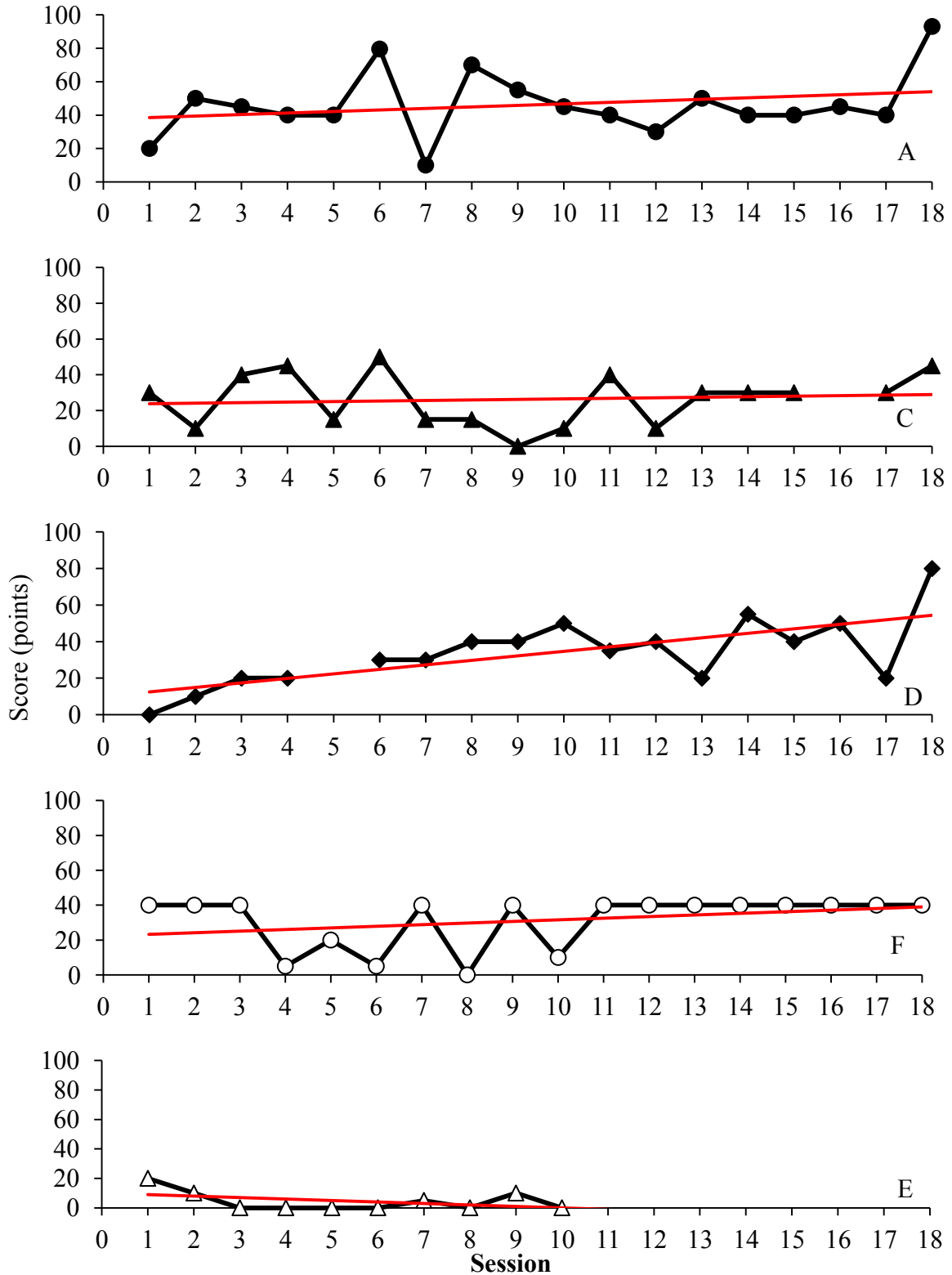
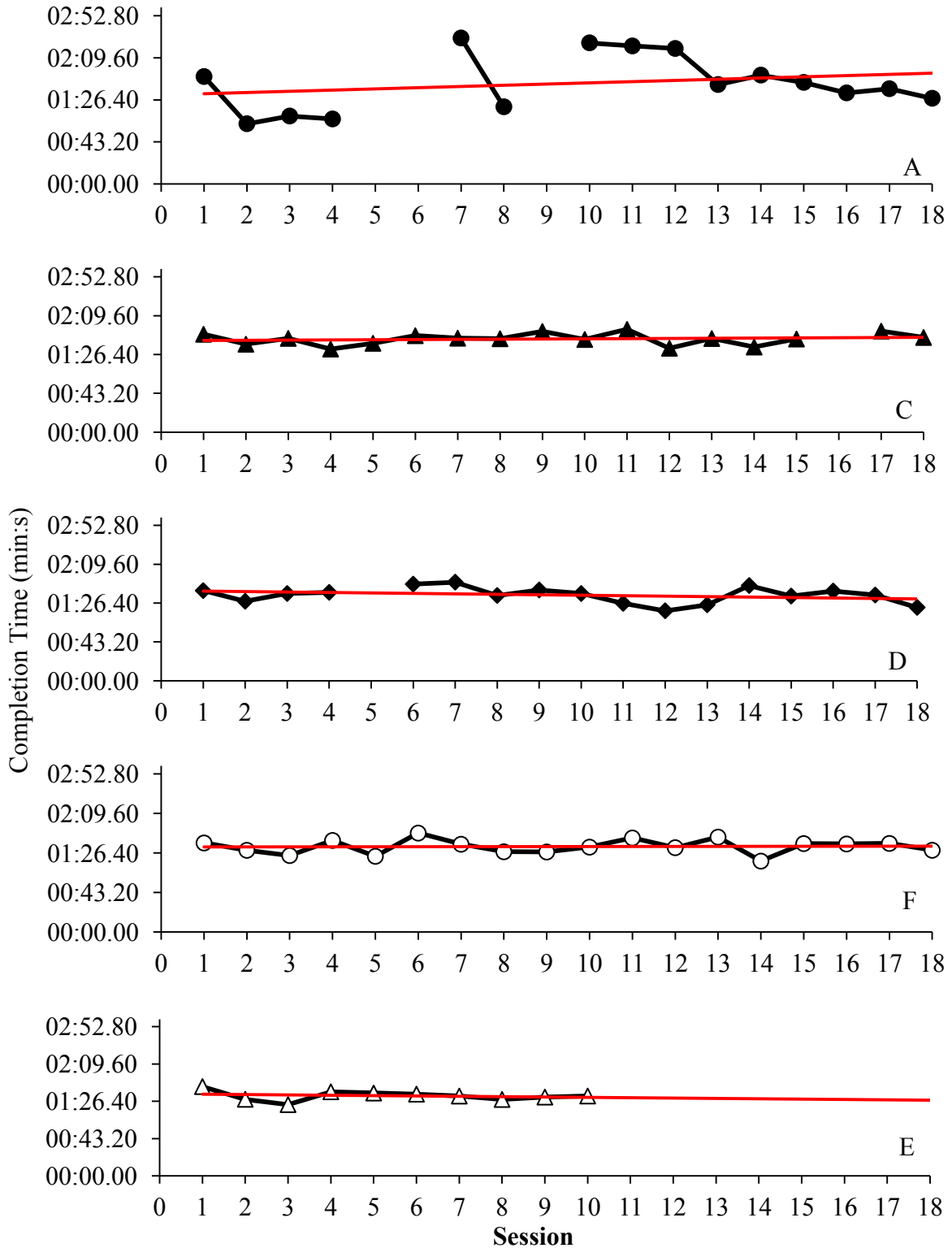


Figure 4.30

*Individual Snowboard Slalom Results*



## Chapter Five: Summary and Conclusions

Two studies were undertaken to investigate the use of the WiiFit as a therapist supervised, multi-directional balance-training intervention for children with developmental disabilities (DD). We sought to examine the effects of this intervention on the balance, strength, gait velocity (GV), and activities and participation of children with DD. These studies were among the first to investigate the effects of a balance-training intervention using the WiiFit with a multiple component model based on the ICF model. We assessed several measures of body structures and function, and activities and participation. Across the two studies there were 10 participants: one with autism spectrum disorder (ASD), six with cerebral palsy (CP), one with developmental delay, one with Down syndrome (DS) and one with sensory processing disorder. All participated in a therapist directed 6 week intervention, 3 times per week for 30 minutes.

The dependent variables included in these studies were balance, hip abductor strength (HAS), GV, and activities. Balance was assessed with clinical and laboratory measures. Laboratory measures included center of pressure (COP) area and velocity with eyes open (EO) and eyes closed (EC), and time to boundary (TTB) mean minima and standard deviation (SD) in the anterior-posterior (AP) and medial-lateral (ML) directions with EO and EC. Clinical measures of balance were the timed up and go (TUG) in the pilot study, single leg stance time (SLST) in study two, and weight bearing symmetry (WBS) in both studies. It was important to utilize both clinical and laboratory measures because of the different information that they provide (De Kegel et al., 2010).

Table 5.1 presents a summary of the results from both studies. Participants were assigned a score of positive (+), negative (-) or no change (o) based on their results from the intervention phase. Positive and negative scores were designated based upon either the trend (*C* statistic), or points above or below the SD bands, or for WBS the number of points within the 48-52% range. For participants that did not have a significant trend ( $Z < 1.645$ ) or three or more consecutive points above or below the SD bands a “no change” (o) score was given.



## Measures of Body Structures and Function

### Balance

Results from these two studies demonstrated change primarily in the laboratory measures. When looking at COP area with EO of the 10 total participants there were 5 participants (2, 3, A, C, E) who had a therapeutic change and 5 participants with no change. For those participants with a therapeutic change their average improvement rate difference (IRD) between the two studies was large (0.94). There were significant decreases in COP area with EC for 5 (2, 3, 4, A, C) of the 8 participants and a large average IRD (0.94). For COP velocity there were decreases for three participants with EO (2, 5, A) and EC (2, 3, A). While there were fewer than half of the total participants with therapeutic change in COP velocity, those participants that decreased their velocity had a large change (IRD= 0.88 EO, 0.80 EC). Our results are consistent with other investigations that studied children with DD following balance training. Specifically, that COP area and velocity decreased following a balance-training intervention (Ledebt et al., 2005; Shumway-Cook et al., 2003). Changes in COP area and velocity may be attributed to the balance training intervention requiring the participants to balance on the small surface area of the Wii balance board. This required the participants to become more adept at moving their bodies within a small space. While therapeutic changes in COP area were observed for some participants, many participants demonstrated no change. For all of the balance measures with EO, except COP area, the majority of participants demonstrated no change. Andrysek and colleagues (2012) also reported no change in COP excursion measures for some of their participants following balance training with the WiiFit. In our studies participants 1 and F may have demonstrated no change in COP area and velocity because their values were already similar to that of typically developing (TD) children.

Participant 5, a child with spastic diplegia CP, demonstrated a significant increase in COP velocity with EC during the intervention phase. For her the majority of balance measures with EC (COP velocity, TTB mean minima ML, TTB SD AP and ML) had counter-therapeutic changes. Increases in her velocity may be explained by anxiety in standing with EC, and she often required a re-administration of a trial due to excessive

movements. Because the change only occurred during EC testing, it may be conjectured that she was dependent on visual input. In fact, participant 5 decreased (therapeutic) her COP velocity during intervention, indicating that a visually directed balance training program improved her rate of sway with EO, possibly increasing her dependence on visual stimuli, thus creating increased COP velocity with EC. There are two other explanations for her COP velocity with EC increase; the evaluation of balance abilities occurred before intervention, thus a carryover effect was required to demonstrate change and secondly, she may have exhibited learning effects during the intervention phase. During the first half of the intervention phase she had an elevated COP velocity with EC, but during the last seven sessions she stabilized about the baseline mean and continued this at follow up, which suggest learning and refinement occurred. During motor learning there are increases in variability and behaviors may worsen before returning to their previous state (Adi-Japha et al., 2008; Adolph, 2008; Adolph & Robinson, 2008; Kamm et al., 1990; Thelen et al., 1996).

For the TTB mean minima measure there were significant increases identified, indicating the children had an increased time to make corrections to postural sway before falling. This was demonstrated in one participant (2) in the AP direction with EO and four participants (1, 2, 5, A) during testing with EC. Increases were also observed for TTB mean minima in the ML direction with EO (participants 2, 4) and EC (participants 1, 2). Effect sizes demonstrated large changes occurred in TTB mean minimas even though there were never a large percentage of participants with therapeutic change between the two studies. for TTB mean minima with EO, the effect sizes indicated large changes did occur (IRD= 1.00 AP, 0.80 ML). Similar to the EO condition there was not a majority with therapeutic change with EC, but TTB mean minima in the AP direction with EC had half the participants with a therapeutic change and half with no change. That half that demonstrated a therapeutic change with EC in the AP direction also had a large effect (0.83). While TTB had not been utilized in a population this young or with DD, increases in TTB mean minima in both AP and ML with EO and EC have been found following intervention for those with chronic ankle instability (Hoch & McKeon, 2011; McKeon et al., 2008). For many participants during the intervention phase there was increased variability of TTB mean minima as compared to baseline. The increased variability

during the intervention phase may be another reflection of the changes in motor control and a learning paradigm.

In the TTB measures there were increases in variability of postural control as measured via the SD of TTB. Increases in SD of TTB indicate that children had more strategies available to maintain their balance and were found in the AP direction with EO (participants 2 and D) and EC (participants 2 and A), as well as the ML direction with EO (participants 2, 4, F) and EC (participant 1). As in the TTB mean minima data the majority of participants demonstrated no therapeutic changes, but those that did exhibit therapeutic changes had large effects, with an average IRD of 1.00 for TTB SD ML with EO and EC and AP with EC. Variability in postural control and movement for children with DD is important to examine and facilitate so that these children have an increased repertoire of strategies to explore their environments and interact with their peers (Dusing & Harbourne, 2010; Hadders-Algra, 2010; Vereijken, 2010). Similar changes in TTB SD during EO and EC conditions were reported for adults with chronic ankle instability, though only in the AP direction (Hoch & McKeon, 2011; McKeon et al., 2008). The differences between our results and those from other TTB studies may be the differences in stance. A SLS protocol was used in the chronic ankle instability studies, while ours utilized dual limb. There is greater sway in dual limb stance in the ML direction than SLS, but for children with DD they are more impaired in the ML direction in gait and stance than the AP direction (Agiouvasitis et al., 2009b; Fournier, 2008; Hsue et al., 2009a, 2009b; Kubo & Ulrich, 2006a; Vernazza-Martin et al., 2005). Improvements in the ML direction through COP measures have also been reported for a child with DS (Berg et al., 2012) and children with lower extremity amputations following a home program utilizing the WiiFit (Andrysek et al., 2012). In addition, there were differences in population characteristics from our studies and those with chronic ankle instability, as children with DD have global impairments in motor control and coordination (Rast & Harris, 1985; Schmitz, Martineau, Barthélémy, & Assaiante, 2003; Zaino, 1999) and do not have mature responses to balance threats (Burtner et al., 2007; Kohen-Raz et al., 1992; Shumway-Cook & Woollacott, 1985a). Of the measures of ML control in our studies there were eight instances of positive outcomes, and nine in the AP direction, therefore though the participants were thought to have less stability and variability in the ML

direction, there were not greater changes in the ML direction following intervention. The participants that did change in the ML direction were those with CP.

As in the COP data in our studies, there were four TTB variables across three participants that had counter-therapeutic outcomes. Three of the four variables had only one participant per measure have a negative outcome (Table 5.1). There were two participants (A, F) who performed worse for TTB mean minima in the AP direction with the EO. Participants A and F had decreased TTB measures without corresponding changes in COP area and velocity. Further evaluation of participant A's TTB mean minima data demonstrated that his negative outcome was not maintained at follow up and was above the upper SD band, thus the intervention phase may have been a learning phase with refinement occurring at his follow up. Similar results were displayed for participant F in TTB mean minima and SD AP with EO; there were decreases during the intervention phase and a return to baseline levels at follow up. The discontinuation of negative trends and subsequent shifts in TTB values at follow up suggest a learning and refinement of postural control abilities. Participant 5's counter-therapeutic results were with EC for TTB mean minima ML, and SD AP and ML. The mean minima and SD decreases correspond to her increased COP velocity with EC. This finding can be explained by the concept that as velocity increased she had a decreased time to make corrections. It is important to note that while none of the counter-therapeutic outcomes continued at maintenance and may be attributed to motor learning, the return to baseline levels could also be due to the removal of the intervention.

There was no significant change in more than half the participants in any laboratory measure, suggesting that the intervention had a minimal effect across participants. Laboratory measures of balance with at least half demonstrating therapeutic changes were COP area EO and EC and TTB mean minima in the AP direction with EC. Examining the laboratory results by diagnoses, the therapeutic changes were frequently identified in children with spastic diplegia CP. Overall, the therapist supervised 6 week video game based balance training intervention had no significant effect on the laboratory measures of balance.

The clinical measures were not as sensitive to change as the laboratory measures and the majority of participants did not have significant changes. Only participant 2

improved in the TUG in the pilot study. Because of the lack of change in the pilot study, SLST was selected for study two as it was thought to be more sensitive to change (De Kegel et al., 2010). Like the TUG results, only one participant (D) demonstrated an increase in SLST. One of the interesting findings about SLST was that 4 of the 5 participants were unable to maintain SLS for any significant length of time. Participant A reached a ceiling effect for SLST during baseline and had no opportunity for improvement during intervention. To combat the ceiling effect in future studies it is recommended that SLST be conducted with EC for those that maximize SLST with EO, as SLST with EC is more discriminative than with EO (De Kegel et al., 2010).

Results from WBS data were similar to TUG and SLST results. Four participants (1, 2, C, D) demonstrated improvements in symmetry, six did not change. Diagnoses of participants that improved WBS included spastic diplegia CP, sensory processing disorder, and developmental delay. Greater gains were anticipated in children with hemiplegia CP (participants 3 and 4) because of the significant impairments on the involved side, though children with diplegia CP also had one lower extremity more involved (Wingert et al., 2009). Of the four participants with improved WBS only participants 1 and 2 with spastic diplegia CP had significant changes in TTB measure of ML control. With only half demonstrating changes in TTB and WBS these results suggest that WBS results from the WiiFit video game are not recommended to track changes in WBS. Though there are several studies that report the Wii balance board to be sensitive to body sway and movements (Clark et al., 2010; Schlueter et al., 2010; Shih, Chen, & Shih, 2012; Shih, Chung, Shih, & Chen, 2011; Shih, Shih, & Chiang, 2010) there is only one study that investigated WBS (Gras et al., 2009), thus further investigation regarding WiiFit WBS is necessary. With the lack of changes in WBS in conjunction with changes in TTB ML measures it appears that WBS from the WiiFit is not sensitive to change. WBS has not been measured in children with DD during static stance, only during gait (O'Reilly, Hunt, Thomas, Harris, & Burns, 2009; White et al., 1999), so measuring WBS with a dual force platform technique as in the stroke literature may be beneficial (Dault et al., 2003; de Haart et al., 2005).

While the measures of balance suggest that the intervention had little effect due to minimal changes being identified, anecdotal parent reports suggest qualitative changes

were occurring in the participants. Multiple parents from both studies reported their children appeared to be tripping and falling less, and were more coordinated and confident during and following the study. It can be inferred that motor control and coordination improved, because participants' scores from the games increased during the intervention, and movement became more refined for all but two participants (5 and E). The treating therapist noted that as the intervention progressed participants used smaller movements to accomplish the goals of the games and had fewer losses of balance during the intervention. The participants also became more efficient in their movements during game play. In the early weeks of the intervention the participants often used multiple strategies to try to succeed at the game, but as the weeks progressed the strategy exploration diminished, until a new challenge was presented. Of the two participants (5 and E) that did not progress, participant 5 was able to verbalize the goals of the games and movements required, but she was not able to perform the coordinated movements to be successful at the games. Her lack of progress on the majority of the games was not due to lack of effort or cognition, but underlying motor control deficits. In contrast, participant E was unable to verbalize the goals of the games or the movements required; his cognitive deficit was the hindrance.

Parents of participants also relayed that their child's therapists reported balance seemed improved following the study, though no quantitative or qualitative explanations were given. It is difficult to discern if there were changes outside of the study, or if these changes were the result of knowledge that these children participated in a balance training intervention. Future research should consider parent interviews or a simple questionnaire asking how frequently the child trips and falls per week to explore this anecdotal information.

The effects of the therapist supervised 6 week video game based balance training intervention on the balance of children with DD were minimal. Of the 15 variables that explored components of balance there were no instances where a majority of participants made therapeutic gains, and only three variables (COP area EO and EC, TTB mean minima AP EC) displayed any therapeutic result in half of the participants. There were eight instances of counter-therapeutic changes during the intervention phase for four participants (Table 5.1). Thus the demands of this balance training intervention were

insufficient to make significant changes to the sensory and motor systems of postural control in these children with DD.

### **Gait Velocity Results**

The results from these studies suggest that GV may be changeable during and following balance training. Five participants increased GV, four remained constant, and one decreased during intervention (Table 5.1). Children with spastic diplegia CP (2 participants) increased their GV, as well as the participants with spastic hemiplegia CP (1 participant), ASD, and developmental delay. While children with CP and with DS, have slower GV than their TD peers (Kubo & Ulrich, 2006a; Wheelwright, Minns, Elton, et al., 1993; Wheelwright, Minns, Law, et al., 1993; White et al., 1999), our results found that the majority of GV improvements were in children with CP. Even though the pilot study participants had GV that were considered fast for children with CP, two participants were able to increase GV. While GV was hypothesized to increase, it only increased in half of the participants, with a moderate effect size of 0.59 for participants with a therapeutic change. The massed practice weight shifting that occurred during intervention may have provided the necessary stimulus to improve the impaired rhythm of gait for children with CP (Iosa et al., 2012; Liao et al., 1997). Further investigation is necessary to determine what components of balance training are optimal to increase GV in children with DD.

GV is a component of endurance and efficiency. Children with CP and DS have increased energy output during gait and decreased efficiency compared to their peers (Agiovlasitis et al., 2009b; Johnston, Moore, Quinn, & Smith, 2004; Thomas, Buckon, Russman, Sussman, & Aiona, 2011; Ulrich, Haehl, Buzzi, Kubo, & Holt, 2004). When more energy is expended on ambulation it decreases energy available for activities and participation. Five participants increased GV and may have improved their endurance and gait efficiency. Two participants that increased GV also increased their activities, suggesting that activity increases may be related to increases in GV.

### **Strength of the Hip Abductors**

Strength improvements of the hip abductors were not expected in these studies, it was hypothesized that strength would remain constant. Four participants increased their HAS and six remained constant (Table 5.1). The participants that did increase their HAS



had an overall small effect (0.26). These results suggest that strength may increase during a non-specific strength training intervention for children with DD. Increases were demonstrated in two participants with spastic diplegia CP, one with spastic hemiplegia CP, and one with sensory processing disorder. Increasing the strength of the hip abductors is important because they relate to balance (Lowe et al., 2004), function (Dichter, 1994; Eek & Beckung, 2008; Ross & Engsborg, 2007), and gait (Metaxiotis et al., 2000). Increases in strength of this muscle group are hypothesized to have carryover to improvements in GV, balance, gait mechanics and functional abilities (Dallmeijer, Baker, Dodd, & Taylor, 2011; Damiano et al., 2010; Dichter, 1994; Gupta et al., 2011). Participants 2, 3 and F had increases in both HAS and GV, which provides further support for the relationship between HAS and GV. Further, these participants (2, 3) also demonstrated increases in the Activities Scale for Kids, performance version (ASKp). Strength of the hip abductors should be monitored in future studies, as well as the relationships between HAS and gait, balance, and function.

Strength training in addition to balance training may add the component necessary to generate greater changes in balance, GV and activities and participation. There is minimal literature reporting the combination of strength and balance training, but it might be an effective intervention for children and adults with DD (Gupta et al., 2011; Hayakawa & Kobayashi, 2011; Katz-Leurer et al., 2009; Tsimaras & Fotiadou, 2004).

### **Measures of Activities and Participation**

Increasing and improving activities and participation of children with DD is a common goal. The pilot study demonstrated significant increases in activities and participation through the ASKp with 3 of the 5 participants improving. During study two the ASKp return rate was very poor, with only three participants returning questionnaires, so no effects were found. The summary results were disheartening with only 3 (participants 2, 3, 5) of the 9 demonstrating improvements. The original hypothesis was there would be no change in activities or participation. Thus the increases in participation and activities suggest that change may be possible. Increases in participation and activities have been reported following hippotherapy for children with balance deficits (Silkwood-Sherer, Killian, Long, & Martin, 2012) and those with CP (Frank, McCloskey,



& Dole, 2011). The majority of literature investigates the patterns and preferences of participation for children with DD, and it has only recently begun to be used as an outcome measure. More research needs to incorporate activities and participation as an outcome measure.

Parents reported that participants became more confident at playing active video games and were more likely to choose an active game following the study than prior. Parents also reported that active video games could now be a family activity and some hoped it would become a peer-based activity. Giving children with DD the confidence and physical capabilities to play active video games with their TD peers without an adult facilitator is an important step to increasing overall participation and activities. The role of the family, opportunities for social interaction with TD peers, and participation in rehabilitation services are important elements to increase participation of children with DD (Barr & Shields, 2011; Majnemer et al., 2008). Our anecdotal findings from parent reports are supported by a recent study where parents reported that video games were a useful intervention (Sandlund, Dock, Hager, & Waterworth, 2012).

All participants from both studies reported the intervention to be enjoyable and challenging. The WiiFit balance games have also been reported to be enjoyable for healthy adults, though not challenging (Brumels et al., 2008). Differences in our results and that of Brumels and colleague's (2008) study may be attributed to population differences. Significant game improvements were found for 8 of 10 participants. While participant 5 did not make significant improvements on the games, anecdotally she demonstrated improved coordination during game play and verbalized the goals and required movements of the games. Her poor motor control limited her ability to be successful at the games. Children with CP have an impaired ability to interpret the source of movement, most likely due to their impairments in visual perception and proprioception (Ritterband-Rosenbaum et al., 2011), which may have been the primary impairment impacting participant 5's progress. Specifically with participant 5's counter-therapeutic trends in her EC balance measures, her proprioception is likely very impaired. In contrast to participant E who's poor game results are likely due to his cognitive impairment. Inspecting the rate of improvements among the participants and the number of therapeutic changes in outcomes measures revealed no differences.

Most participants with therapeutic changes in outcome measures were those who progressed to the higher difficulty settings of the games, though not to the greatest difficulty setting, and were children with CP. These participants with CP that made the greatest progress in both games and outcome measures were not the Gross Motor Function Classification System (GMFCS) level 1's, but level 2. Participants at GMFCS level 2 have greater impairments than those at 1 and have a greater opportunity to improve. Specifically, participant 2, who improved in every balance measure with EO, and all but one with EC, was highly internally motivated. The combination of internal motivation and greater physical impairment may be characteristics of responders to intervention.

Therapeutic changes following Wii intervention have been reported in upper extremity control and dexterity (Berg et al., 2012; Wuang et al., 2011), running speed and agility (Berg et al., 2012; Wuang et al., 2011), postural control (Andrysek et al., 2012; Berg et al., 2012; Deutsch et al., 2008; Liu et al., 2009b), functional mobility (Deutsch et al., 2008), and visual perception (Deutsch et al., 2008). Studies utilizing the WiiFit solely as a balance training intervention for children with DD reported balance results similar to ours, with therapeutic changes in only a small percentage of balance variables (Andrysek et al., 2012; Liu et al., 2009b). Studies that reported more significant therapeutic changes with the Wii were done in the clinic over a longer duration (Wuang et al., 2011) and utilized the Wii Sports rather than WiiFit (Deutsch et al., 2008; Wuang et al., 2011). The difference between our studies and other studies (Andrysek et al., 2012; Berg et al., 2012) using the WiiFit as a home program was in our study, a therapist directly supervised the home program. Having a licensed physical therapist present during intervention allowed the therapist to provide live feedback about changing strategies and progressing participants to more challenging levels, thus providing high treatment fidelity for our studies. Even with a therapist directing and supervising the video game based balance-training intervention there were minimal effects on most outcome measures. It is a possibility that having the PT present and directing every session was a detrimental effect on the participants' performance, as it may have decreased the motivation and social aspects of the games (Sandlund et al., 2012).

A compounding factor in both our studies was that five participants owned and used a Wii prior to the study; three of them also owned the WiiFit (1, 2, 5). While most parents reported their child did not consistently play the games preselected for our studies the familiarity with them is a variable that cannot be ignored. Participants (1, 2, 5) that owned a WiiFit were instructed not to play the games used in the study during the study time frame. Another factor was that three participants (1, 2, 3) from the pilot study received significantly more rehabilitation services than all other participants, though this probably did not affect the outcomes.

### **Suggestions for Future Research**

The results from these two studies demonstrate that further research needs to be undertaken to better understand what components of balance training are most likely to influence the sensory and motor systems of balance, as well as strength, GV, and activities and participation. Single subject research designs continue to be appropriate to identify responders and non-responders, though traditional group designs could be used with fewer dependent variables. While other studies have reported more conclusive results using the Wii for children with DD (Berg et al., 2012; Deutsch et al., 2008; Liu et al., 2009b; Wuang et al., 2011), they were less rigorous in playing of the video games. Participants of these other studies appeared to have greater choice in games and number of repetitions. Continued research with the WiiFit might incorporate a more flexible design in reference to games and repetitions, but continue to use the therapist directed and monitored design presented here to provide for high treatment fidelity. Without the consistent feedback from a therapist the WiiFit loses its validity as an intervention (Deutsch et al., 2011). Longer interventions from 8 (Berg et al., 2012) to 24 weeks (Wuang et al., 2011), or shorter interventions with a higher frequency (Brien & Sveistrup, 2011; Shumway-Cook et al., 2003) may produce more consistent results and provide the added demand necessary to make significant changes. Future investigators may want to analyze behaviors such as reaction time and anticipatory postural adjustments (Liu et al., 2009b), as these may improve with this intervention. When investigating changes in balance during and following intervention it is important to use clinical and laboratory measures (De Kegel et al., 2010), and the addition of measures such as a fall history and

tracking falls may provide greater insight. Future research should continue to address the impact of balance training on activities and participation for children with DD. The ASKp has recently been revised and researchers and clinicians may want to consider using the ASKp-38 (Bagley et al., 2011).

The rigidity of preselected games for a predetermined number of minutes was not effective in making improvements in balance therefore adding a component such as strength training may provide the additional demand necessary to make therapeutic changes to more variables (Gupta et al., 2011). Specifically targeting the hip abductors may facilitate improvements in GV that can carryover into activities and participation.

### **Conclusions**

While the overall results do not demonstrate any clear improvements after participating in a therapist directed video game based balance training intervention, there were multiple measures where half of the participants improved. This suggests that the WiiFit balance games used 3 times per week for 6 weeks are not enough to improve balance, GV, HAS, and activities and participation in children with DD. The lack of consistent improvements in many of the measures suggest that additional adjunct therapeutic intervention may be necessary to improve postural control, GV and HAS of children with DD, as well as activities and participation. While these two studies did not find the WiiFit balance games to be an effective intervention, the results do suggest that it could be a component of intervention, but not the intervention alone.

Table 5.1

*Summary of Results*

Participant	WBS	COP Area		COP Velocity		TTB MM AP		TTB MM ML		TTB SD AP		TTB SD ML		TUG	SLST	GV	HAS	ASKp
		EO	EC	EO	EC	EO	EC	EO	EC	EO	EC	EO	EC					
<b>Pilot Study</b>																		
1	+	0	0	0	0	0	+	0	+	0	0	0	+	0		0	0	0
2	+	+	+	+	+	+	+	+	+	+	+	+	0	+		+	+	+
3	0	+	+	0	+	0	0	0	0	0	0	0	0	0		+	+	+
4	0	0	+	0	0	0	0	+	0	0	0	+	0	-		-	0	0
5	0	0	0	+	-	0	+	0	-	0	-	0	-	0		0	0	+
<b>Study #2</b>																		
A	0	+	+	+	+	-	+	0	0	0	+	0	0		0	+	0	0
C	+	+	+	0	0	0	0	0	0	0	0	0	0		0	0	+	0
D	+	0		0		0		0		+		0			+	+	0	0
F	0	0	0	0	0	-	0	0	0	-	0	+	0		0	+	+	0
E	0	+		0		0		0		0		0			0	0	0	
Count +	4	5	5	3	3	1	4	2	2	2	2	3	1	1	1	5	4	3
Count o	6	5	3	7	4	7	4	8	5	7	5	7	6	3	4	4	6	6
Count -	0	0	0	0	1	2	0	0	1	1	1	0	1	1	0	1	0	0

*Note.* WBS= weight bearing symmetry; COP= center of pressure; TTB MM= time to boundary mean minima; TTB SD= time to boundary standard deviation; AP= anterior posterior; ML= medial lateral; EO= eyes open; EC= eyes closed; TUG= timed up and go; SLST= single leg stance time; GV= gait velocity; HAS= hip abductor strength; ASKp= Activities Scale for Kids, performance version; + positive results; 0 no change; - negative results; empty= not tested

**Consent to Participate in a Research Study**

**USE OF WiiFit™ ON BALANCE AND FUNCTION  
IN CHILDREN WITH CEREBRAL PALSY**

**WHY ARE YOU BEING INVITED TO TAKE PART IN THIS RESEARCH?**

Your child is being invited to take part in a research study about balance training using the Nintendo WiiFit™. Your child is being invited to take part in this research study because your child has cerebral palsy and is between 5 and 10 years old and can stand independently. If your child volunteers to take part in this study, your child will be one of about six people to do so through the University of Kentucky.

**WHO IS DOING THE STUDY?**

The person in charge of this study is Gina C. Siconolfi-Morris, PT, a doctoral candidate in the Rehabilitation Sciences Doctoral Program at the University of Kentucky. Susan Effgen, PhD, PT and Carl Mattacola, PhD, ATC from the Rehabilitation Sciences Doctoral Program at the University of Kentucky are guiding her in this research. There may be other people on the research team assisting at different times during the study.

**WHAT IS THE PURPOSE OF THIS STUDY?**

The purpose of this study is to find out if using a video-game based balance training program (Nintendo WiiFit™ balance games) will improve the balance, walking ability and leg strength of children with cerebral palsy.

By doing this study, we hope to learn if active video games (Nintendo WiiFit™ balance games) can be used to improve the balance, walking ability, leg strength and activities of children with cerebral palsy.

## ARE THERE REASONS WHY YOU SHOULD NOT TAKE PART IN THIS STUDY?

Your child should *not* take part in this study if he/she:

- does not have cerebral palsy
- is unable to stand for 3 minutes without support
- has had an ear infection in the past 6 weeks
- has an uncontrolled seizure disorder
- has hearing loss

## WHERE IS THE STUDY GOING TO TAKE PLACE AND HOW LONG WILL IT LAST?

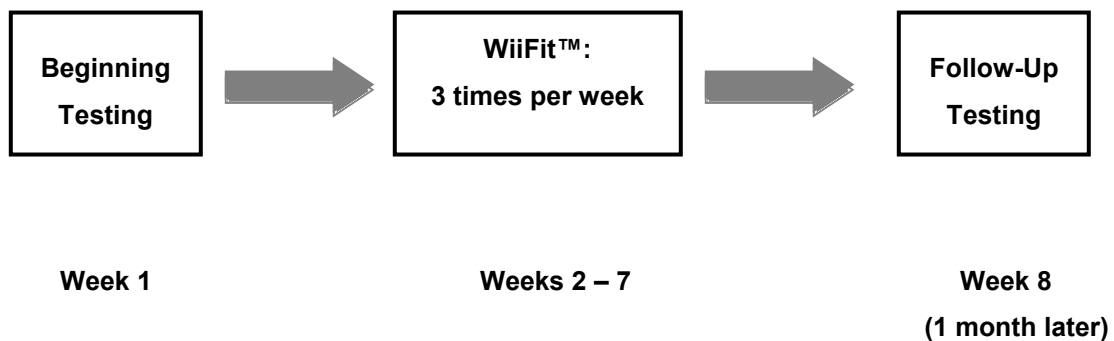
The research will occur at your home. There will be 24 visits to your home that will each last about 1 hour; both you and your child will need to be home. The total amount of time you and your child will be asked to volunteer for this study is about 24 hours over the next 3 months.

## WHAT WILL YOUR CHILD BE ASKED TO DO?

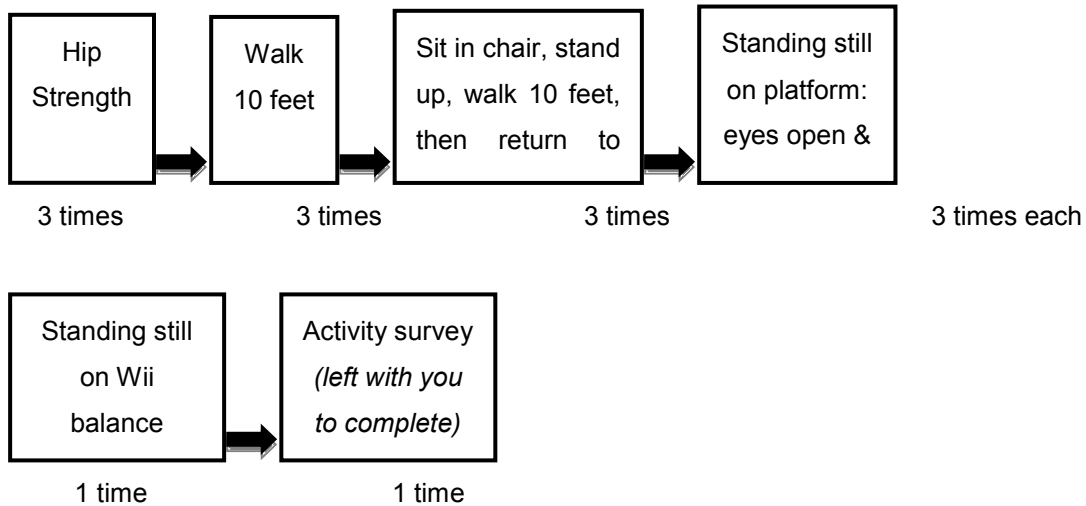
Your child will be assigned to one of two groups by chance. Both groups get the same treatment. The only difference is how long your child is tested in the beginning of the study. There are 3 parts of the study:

1. Beginning Testing, 2. WiiFit™ and 3. Follow-Up Testing.

Below is a timeline of the entire study.



During *Beginning Testing* you will be asked to complete a brief medical history for your child at the first visit. Your child will be asked to stand on a platform to measure the ability to stand still with eyes open and closed 6 times. Your child will be asked to stand on the Wii balance board with eyes open to measure the ability to stand still. Your child will be asked to walk about 10 feet. Your child will be asked to sit in a chair, stand up, walk about 10 feet and then return to sitting in the chair. You and your child will be asked to fill out a survey about activities that your child does at school, home and in the community. All of these tests are like those usually done during physical therapy. These tests will be given between 3 and 5 times over the first week. The tests are shown below in a timeline.



During *WiiFit™* your child will be asked to play the Nintendo *WiiFit™* balance games 3 times per week for 6 weeks, for 30 minutes each time. The balance games involve standing on two feet and shifting the body left, right, front and back to play the games. Your child will choose the order that the pre-selected games are played. The balance games are considered experimental but are played by children around the world. It is not known if they will improve your child's balance.

One time per week during *WiiFit™* the tests given during *Beginning Testing* will be given again. The last day of the 6 weeks all the tests will be given again.

During *Follow-Up Testing* your child will be given all of the tests given *Beginning Testing*.

#### **WHAT ARE THE POSSIBLE RISKS AND DISCOMFORTS?**

- Your child may feel like he/she is going to fall or will start to fall.
  - A safety belt must be worn and the researcher will catch your child from falling.
- Your child may feel dizzy.
  - This should go away after finishing the tests or game play.
- Your child may feel sick to the stomach.
  - This should go away after stopping the games.
- Your child may experience a seizure from playing the video games.
  - This is a serious, but very rare complication and will need to be addressed by medical personnel as soon as possible.

There is always a chance that any medical treatment can harm you, and the investigational treatment in this study is no different. In addition to the risks listed above, you may experience a previously unknown risk or side effect.



### **WILL YOUR CHILD BENEFIT FROM TAKING PART IN THIS STUDY?**

There is no guarantee that your child will get any benefit from taking part in this study. However, some people have experienced better balance when walking and playing after balance training and your child may enjoy playing the games. Your child's willingness to take part may, in the future, help therapists better treat others who have your child's condition.

### **DOES YOUR CHILD HAVE TO TAKE PART IN THE STUDY?**

If you and your child decide to take part in the study, it should be because your child really wants to volunteer. You and your child will not lose any benefits or rights you would normally have if you and your child choose not to volunteer. Your child can stop at any time during the study and still keep the benefits and rights had before volunteering. If you and your child decide not to take part in this study, the decision will have no effect on the quality of medical care your child receives.

### **IF YOUR CHILD DOESN'T WANT TO TAKE PART IN THE STUDY, ARE THERE OTHER CHOICES?**

If your child does not want to be in the study, there are no other choices except not to take part in the study.

### **WHAT WILL IT COST YOU AND YOUR CHILD TO PARTICIPATE?**

It will cost you and your child nothing to participate.

### **WHO WILL SEE THE INFORMATION THAT YOU GIVE?**

We will make every effort to keep private all research records that identify your child to the extent allowed by law.

Your child's information will be combined with information from other people taking part in the study. When we write about the study to share it with other researchers, we will write about the combined information we have gathered. Your child will not be personally identified in these written materials. We may publish the results of this study; however, we will keep your child's name and other identifying information private

We will make every effort to prevent anyone who is not on the research team from knowing that you and your child gave us information, or what that information is. Your child's paper records will be kept in a locked office that only Gina Siconolfi-Morris, PT, Carl Mattacola, PhD, ATC and Susan Effgen, PhD, PT will be able to get to. Your child's computer records will be stored on a computer that will be kept in a locked office that no one else will be able to get to.

You should know, however, that there are some circumstances in which we may have to show your information to other people. If your child falls we will need to fill out paperwork with your

child's name and information about what happened. For example, the law may require us to show your information to a court or to tell authorities if you report information about a child being abused or if you pose a danger to yourself or someone else.

Officials of the University of Kentucky may look at or copy pertinent portions of records that identify your child.

#### **CAN YOUR CHILD'S TAKING PART IN THE STUDY END EARLY?**

If your child decides to take part in the study your child still have the right to decide at any time that they no longer want to continue. Your child will not be treated differently if your child decides to stop taking part in the study.

The individuals conducting the study may need to withdraw your child from the study. This may occur if your child is not able to follow the directions they give them or if they find that your child being in the study is more risk than benefit to them.

#### **IS YOUR CHILD PARTICIPATING OR CAN YOUR CHILD PARTICIPATE IN ANOTHER RESEARCH STUDY AT THE SAME TIME AS PARTICIPATING IN THIS ONE?**

Your child may take part in this study if your child is currently involved in another research study. It is important to let the investigator/your child's doctor know if your child is in another research study. You should also discuss with the investigator before you and your child agree to participate in another research study while your child is enrolled in this study.

#### **WHAT HAPPENS IF YOUR CHILD GETS HURT OR SICK DURING THE STUDY?**

If you believe your child is hurt or if your child gets sick because of something that is due to the study, you should call Gina Siconolfi-Morris at 859-218-0578 or 207-450-5944 immediately.

Gina Siconolfi-Morris will determine what type of treatment, if any, which is best for you at that time.

It is important for you to understand that the University of Kentucky does not have funds set aside to pay for the cost of any care or treatment that might be necessary because your child gets hurt or sick while taking part in this study. Also, the University of Kentucky will not pay for any wages you may lose if your child is harmed by this study.

The medical costs related to your child's care and treatment because of research related harm will be your responsibility.

You and your child do not give up your legal rights by signing this form.

**WILL YOUR CHILD RECEIVE ANY REWARDS FOR TAKING PART IN THIS STUDY?**

Your child will receive \$80 for taking part in this study. If your child chooses to withdraw early, your child will be paid \$10 for each week that they participated. The check will be made out to your child. If your child completes the entire study your child will be entered in a drawing to win a Nintendo Wii and WiiFit™ Plus (valued at \$300). The chances at winning the Wii and WiiFit are 1 out of 6.

**WHAT IF YOU OR YOUR CHILD HAVE QUESTIONS, SUGGESTIONS, CONCERNS, OR COMPLAINTS?**

Before you and your child decide whether to accept this invitation to take part in the study, please ask any questions that might come to mind now. Later, if you or your child, have questions, suggestions, concerns, or complaints about the study, you and your child can contact the investigator, Gina Siconolfi-Morris at 859-218-0578 or 207-450-5944. If you or your child have any questions about your rights as a volunteer in this research, contact the staff in the Office of Research Integrity at the University of Kentucky at 859-257-9428 or toll free at 1-866-400-9428. We will give you a signed copy of this consent form to take with you.

**WHAT IF NEW INFORMATION IS LEARNED DURING THE STUDY THAT MIGHT AFFECT MY CHILD'S DECISION TO PARTICIPATE?**

If the researcher learns of new information in regards to this study, and it might change your child's willingness to stay in this study, the information will be provided to you and your child. You may be asked to sign a new informed consent form if the information is provided to you and your child after your child has joined the study.

**WHAT ELSE DO YOU AND YOUR CHILD NEED TO KNOW?**

You will be told if any new information is learned that may affect your child's condition or influence your child's willingness to continue participating in this study.

\_\_\_\_\_  
Name of subject

\_\_\_\_\_  
Signature of person providing permission for subject to participate

\_\_\_\_\_  
Date

\_\_\_\_\_  
Printed name of person providing permission for subject to participate

\_\_\_\_\_  
Relationship to Subject

\_\_\_\_\_  
Name of [authorized] person obtaining informed consent

\_\_\_\_\_  
Date

\_\_\_\_\_  
Signature of Investigator

\_\_\_\_\_  
Date

## **ASSENT FORM**

### **USE OF WiiFit™ ON BALANCE AND FUNCTION IN CHILDREN WITH CEREBRAL PALSY**

You are invited to be in a research study being done by Gina Siconolfi-Morris from the University of Kentucky. Research studies are done when doctors want to find new ways of treating patients. You are invited because you are a child with cerebral palsy between 5 and 10 years old.

We want to see how well you can stand still on a platform, how strong your legs are and how fast you can walk. You will get the chance to play the balance games on the WiiFit™ for 6 weeks. Playing the games on the Wii are usually fun, but you may feel tired, sick or you might fall down.

If you are in the study, I will come to your house 24 times. Sometimes we will just see how well you stand still and sometimes we will play the balance games on the Wii. You will play the balance games on the Wii 3 times a week for 6 weeks. You will play the balance games for 30 minutes. You get to choose what order you play the balance games.

Your family will know that you are in the study. If anyone else is given information about you, they will not know your name. A number or initials will be used instead of your name.

You will get \$80 for participating in this study, \$10 each week. The check will be given to you. You will also get a 1 in 6 chance to win a Nintendo Wii and WiiFit™ if you finish all 24 visits.

If something makes you feel bad while you are in the study, please tell Gina Siconolfi-Morris or your parent. If you decide at any time you do not want to finish the study, you may stop whenever you want. You can ask Gina Siconolfi-Morris or the study assistants questions any time about anything in this study. You can also ask your parent(s) any questions you might have about the study.

Being in the study is up to you, and no one will be mad if you do not sign this paper or even if you change your mind later. You agree that you have been told about this study and why it is being done and what to do.

---

Name of Person Agreeing to be in the Study  
Signed

---

Date

---

Name of Person Obtaining Informed Assent  
Signed

---

Date

---

Signature of Investigator  
Signed

---

Date

Appendix B

Subject ID:

Date:

### Enjoyment Questionnaire

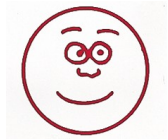
Think about the games you just played the past week. Circle or point to the number or face that best answers the question.

How hard were the games to play?



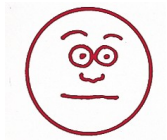
1

Very easy



2

Easy



3

OK



4

A little hard



5

Very hard

How much fun was it to play the games?



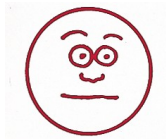
1

Lots of fun



2

A little fun



3

OK



4

Not really fun



5

Not fun at all

What else did you like or not like about the games?

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## Appendix C

### Star Rating System

Each balance game in the WiiFit utilizes a star rating system to allow the participant to know how well they performed. The star rating system utilizes a 0 to four star system with accompanying adjective. Zero stars are awarded if a participant falls below a predetermined minimum for each game, one star is awarded for scoring between a two predetermined amounts, two stars are awarded for scoring above the one star maximum but below the three star minimum, and three and four stars are awarded following the same pattern. The adjectives used for each star rating are:

- One star- Unbalanced
- Two stars- Amateur
- Three stars- Professional
- Four stars- Champion

The score requirements for each game and star level are presented below:

	Soccer Heading (points)	Penguin Slide (points)	Balance Bubble (time)	Table Tilt (points)	Ski Slalom (time)	Snowboard Slalom (time)
One star	1-39	1-24	Did not complete course	1-29	$\geq 0:50.00$	$\geq 0:50.00$
Two stars	40-199	25-79	1:30.00- 0:50.00	30-79	0:49.99- 0:40.00	0:49.99- 0:40.00
Three stars	200-349	80-124	0:49.99- 0:30.00	80-99	0:39.99- 0:30.00	0:39.99- 0:30.00
Four stars	350+	125-150	0:29.99 $\leq$	100+	0:29.99 $\leq$	0:29.99 $\leq$

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## Appendix D

### Baseline Checklist

#### Baseline Checklist

- 1  Sign consent & assent forms
- 1.1  Complete general data sheet
- 1.2  Discuss measures & procedures
  
- 2  **Hip Abductor Strength**
- 2.1  Power on dynamometer
- 2.2  Calibrate dynamometer
- 2.3  Position child supine
- 2.4  "I am going to see how strong your legs are . You are going to push as hard as you can against this for 5 seconds  
(Show dynamometer)
- 2.5  Position dynamometer 5cm proximal to lateral femoral epicondyle on non-impaired leg
- 2.6  "When I say "GO" push as hard as you can. READY , set, GO!" PUSH, PUSH, PUSH, PUSH, PUSH, STOP!"
- 2.7  **Non-impaired leg**  
(1. \_\_\_ 2. \_\_\_ 3. \_\_\_ 4. \_\_\_)
- 2.8  Position dynamometer 5cm proximal to lateral femoral epicondyle on impaired leg
- 2.9  "When I say "GO" push as hard as you can. READY , set, GO!" PUSH, PUSH, PUSH, PUSH, PUSH, STOP!"
- 2.1  **Impaired leg**  
(1. \_\_\_ 2. \_\_\_ 3. \_\_\_ 4. \_\_\_)
  
- 3  **Gait Velocity**
- 3.1  Measure out 3 meter distance
- 3.2  Set-up object at 3 meter mark
- 3.3  Record location, floor type
- 3.4  Clear stopwatch.
- 3.5  "I am going to see how fast you walk. When I say "Go" walk over and touch that object. Do not run."
- 3.6  READY, Set, GO!"  
(1. \_\_\_ 2. \_\_\_ 3. \_\_\_)

#### Baseline Checklist

- 4  **Timed Up and Go**
- 4.1  Set-up folding chair
- 4.2  Seat child in chair, feet flat on floor
- 4.3  "I am going to see how long it takes you to get up from this chair , walk to the object and get back to sitting in this chair .
- 4.4  Clear stopwatch.
- 4.5  "When I say "GO", stand up, walk over to the object, touch it and turn around and walk back to the chair and sit down  
Do not run. Ready, Set, GO!"
- 4.6  (1. \_\_\_ 2. \_\_\_ 3. \_\_\_)
  
- 5  **Center of Pressure and Time to Boundary**
- 5.1  Start-up laptop
- 5.2  Power up forceplate
- 5.3  Connect forceplate to laptop
- 5.4  Open Balance Clinic software
- 5.5  Calibrate (zero out) forceplate
- 5.6  Create patient data file
- 5.7  Load Gina's protocol.
- 5.8  Stand child on forceplate. Center feet horizontally and vertically
- 5.9  Record coordinates of outer corners.
- 5.1  "I am going to see how well you can stand still with your eyes open and closed. Pick something in front of you to look at.  
What are you looking at?"
- 5.11  Child answers.
- 5.12  "When I say "Go" you are going to stand as still as you can looking at \*blank\*. Ready , Set, GO"
- 5.13  (1. \_\_\_ 2. \_\_\_ 3. \_\_\_)
- 5.14  Save trials individually
- 5.15  "Now we are going to do the same thing with your eyes closed. When I say "Go" close your eyes and don't open them until I  
say so. Ready, Set, GO, close your eyes"
- 5.16  (1. \_\_\_ 2. \_\_\_ 3. \_\_\_)
- 5.18  "Open your eyes"
- 5.19  Save trials individually
- 5.20  Power down laptop, forceplate.

### Baseline Checklist

- 6  **Weight Bearing Symmetry**
- 
- 6.1  Plug in Wii  
6.2  Set-up Wii sensor bar  
6.3  Turn on Wii  
6.4  Import Mii or create Mii  
6.5  Load WiiFit CD  
6.6  Enter data as prompted  
6.7  Turn on Wii balance board  
6.8  Have child stand on board  
6.9  Measure & record distance between calcanei & met heads  
6.10  *"I am going to see how well you stand still on this board. You need to look at the TV and focus on the green light."*  
6.11  Load WBS test on WiiFit  
6.12  *"Ready, Set, Go"*  
6.13  Power down Wii and balance board
- 7  **Activities Scale for Kids**
- 
- 7.1  Write child's ID number & date on booklet  
 *"This is a book that asks you about things that you have done in the past week. You and your parents should read each question and choose the best answer. Circle the answer in the book. I will pick up the book from you at my next visit."*
- 8  Have child draw number to determine baseline length  
8.1  Schedule baseline and intervention visits.  
8.2  Give family contact phone numbers.

## Appendix E

### Intervention Checklist with Testing

#### Intervention Checklist with Testing

- 1  Take out intervention data sheet
- 1.1  Discuss procedures
- 2  **Hip Abductor Strength**
- 
- 2.1  Power on dynamometer
- 2.2  Calibrate dynamometer
- 2.3  Position child supine
- 2.4  "I am going to see how strong your legs are . You are going to push as hard as you can against this for 5 seconds (Show dynamometer)
- 2.5  Position dynamometer 5cm proximal to lateral femoral epicondyle on non-impaired leg
- 2.6  "When I say "GO" push as hard as you can. READY , set, GO!" PUSH, PUSH, PUSH, PUSH, STOP!"
- 2.7  **Non-impaired leg**  
(1. \_\_\_ 2. \_\_\_ 3. \_\_\_ 4. \_\_\_)
- 2.8  Position dynamometer 5cm proximal to lateral femoral epicondyle on impaired leg
- 2.9  "When I say "GO" push as hard as you can. READY , set, GO!" PUSH, PUSH, PUSH, PUSH, PUSH, STOP!"
- 2.1  **Impaired leg**  
(1. \_\_\_ 2. \_\_\_ 3. \_\_\_ 4. \_\_\_)
- 3  **Gait Velocity**
- 
- 3.1  Measure out 3 meter distance
- 3.2  Set-up object at 3 meter mark
- 3.3  Clear stopwatch.
- 3.4  "I am going to see how fast you walk. When I say "Go" walk over and touch that object. Do not run."
- 3.5  **READY, Set, GO!"**  
(1. \_\_\_ 2. \_\_\_ 3. \_\_\_)
- 4  **Timed Up and Go**
- 
- 4.1  Set-up folding chair
- 4.2  Seat child in chair, feet flat on floor
- 4.3  "I am going to see how long it takes you to get up from this chair, walk to the object and get back to sitting in this chair . 4.6  (1. \_\_\_ 2. \_\_\_ 3. \_\_\_)
- 4.4  Clear stopwatch.
- 4.5  "When I say "GO", stand up, walk over to the object, touch it and turn around and walk back to the chair and sit down Do not run. Ready, Set, GO!"

#### Intervention Checklist with Testing

- 5  **Center of pressure and Time to boundary**
- 
- 5.1  Start-up laptop
- 5.2  Power up forceplate
- 5.3  Connect forceplate to laptop
- 5.4  Open Balance Clinic software
- 5.5  Calibrate (zero out) forceplate
- 5.6  Create patient data file
- 5.7  Load Gina's protocol.
- 5.8  Stand child on forceplate. Center feet horizontally and vertically
- 5.9  Using pre-recorded coordinates position feet appropriately on board.
- 5.10  "I am going to see how well you can stand still with your eyes open and closed. Pick something in front of you to look at. What are you looking at?"
- 5.11  Child answers.
- 5.12  "When I say "Go" you are going to stand as still as you can looking at \*blank\*. Ready , Set, GO"
- 5.13  (1. \_\_\_ 2. \_\_\_ 3. \_\_\_)
- 5.14  Save trials individually
- 5.15  "Now we are going to do the same thing with your eyes closed. When I say "Go" close your eyes and don't open them until I say so. Ready, Set, GO, close your eyes"
- 5.16  (1. \_\_\_ 2. \_\_\_ 3. \_\_\_)
- 5.18  "Open your eyes"
- 5.19  Save trials individually
- 5.20  Power down laptop, forceplate.
- 6  **Weight Bearing Symmetry**
- 
- 6.1  Plug in Wii
- 6.2  Set-up Wii sensor bar
- 6.3  Turn on Wii
- 6.5  Load WiiFit CD
- 6.6  Enter data as prompted
- 6.7  Turn on Wii balance board
- 6.8  Have child stand on board
- 6.9  Use pre-recorded distances to position feet on WBB
- 6.10  "I am going to see how well you stand still on this board. You need to look at the TV and focus on the green light.
- 6.11  Load WBS test on WiiFit
- 6.12  "Ready, Set, Go"

### Intervention Checklist with Testing

- 7  **Activities Scale for Kids**
- 
- 7.1  Write child's ID number & date on booklet  
 *"This is a book that asks you about things that you have done in the past week. You and your parents should read each question and choose the best answer. Circle the answer in the book. I will pick up the book from you at my next visit."*
- 8  **Games**
- 
- 8.1  *"You are now going to play four of the balance games: Soccer Heading, Balance Bubble, T able Tilt, and Penguin Slide" Each game has to played a set number of times. Soccer heading is 7, balance bubble is 8, table tilt is 5 and penguin slide is 6. It does not matter what order you play the games, you get to choose what order. If you need a break let me know and you can sit down and rest for 2 minutes. Please let me know if you feel like you are going to be sick or if you get dizzy. We will stop if you get dizzy or sick. Any questions?*
- 8.2  Child response.
- 8.3  *"Here is the controller you choose and lets play!"*
- 8.4  Power down Wii when finished.
- 9  **Enjoyment Questionnaire**
- 
- 9.1  Write down child ID number and date on paper
- 9.2  *"Now I am going to ask you how much you enjoyed playing the games and how hard they were to play. I have three questions to ask you. You can answer the questions by pointing to the face or number that is how you feel or reading the words below*
- 9.3  Read question 1
- 9.4  Child response
- 9.5  Read question 2
- 9.6  Child response
- 9.7  Read question 3
- 9.8  Child response
- 10  Confirm next appointment

## Appendix F

### Intervention Checklist (no testing)

#### Intervention Checklist (no testing)

- 1  Take out intervention data sheet  
1.1  Discuss procedures
- 2  **Center of pressure and Time to boundary**
- 
- 2.1  Start-up laptop  
2.2  Power up forceplate  
2.3  Connect forceplate to laptop  
2.4  Open Balance Clinic software  
2.5  Calibrate (zero out) forceplate  
2.6  Create patient data file  
2.7  Load Gina's protocol.  
2.8  Stand child on forceplate.  
2.9  Using pre-recorded coordinates position feet appropriately on board.  
2.10  "I am going to see how well you can stand still with your eyes open and closed. Pick something in front of you to look at. What are you looking at?"  
2.11  Child answers.  
2.12  "When I say "Go" you are going to stand as still as you can looking at \*blank\*. Ready , Set, GO"  
2.13  (1. \_\_\_ 2. \_\_\_ 3. \_\_\_)  
2.14  Save trials individually  
2.15  "Now we are going to do the same thing with your eyes closed. When I say "Go" close your eyes and don't open them until I say so. Ready, Set, GO, close your eyes"  
2.16  (1. \_\_\_ 2. \_\_\_ 3. \_\_\_)  
2.17  "Open your eyes"  
2.18  Save trials individually  
2.19  Power down laptop, forceplate.
- 3  **Weight Bearing Symmetry**
- 
- 3.1  Plug in Wii  
3.2  Set-up Wii sensor bar  
3.3  Turn on Wii  
3.5  Load WiiFit CD  
3.6  Enter data as prompted  
3.7  Turn on Wii balance board
- 3.8  Have child stand on board  
3.9  Use pre-recorded distances to position feet on WBB  
3.10  " I am going to see how well you stand still on this board. You need to look at the TV and focus on the green light on  
3.11  Load WBS test on WiiFit  
3.12  "Ready, Set, Go"

#### Intervention Checklist (no testing)

- 4  **Games**
- 
- 4.1  "You are now going to play four of the balance games: Soccer Heading, Balance Bubble, T able Tilt, and Penguin Slide" Each game has to played a set number of times. Soccer heading is 7, balance bubble is 8, table tilt is 5 and penguin slide is 6. It does not matter what order you play the games, you get to choose what order . If you need a break let me know and you can sit down and rest for 2 minutes. Please let me know if you feel like you are going to be sick or if you get dizzy . We will stop if you get dizzy or sick. Any questions?  
4.2  Child response.  
4.3  Here is the controller you choose and lets play!"  
4.4  Power down Wii when finished.
- 5  Confirm next appointment

## Maintenance Checklist

## Maintenance Checklist

- 1  Take out maintenance data sheet
- 1.1  Discuss measures & procedures
- 2  **Hip Abductor Strength**
- 
- 2.1  Power on dynamometer
- 2.2  Calibrate dynamometer
- 2.3  Position child supine
- 2.4  "I am going to see how strong your legs are . You are going to push as hard as you can against this for 5 seconds (Show dynamometer)
- 2.5  Position dynamometer 5cm proximal to lateral femoral epicondyle on non-impaired leg
- 2.6  "When I say "GO" push as hard as you can. READY , set, GO!" PUSH, PUSH, PUSH, PUSH, STOP!"
- 2.7  **Non-impaired leg**  
(1. \_\_\_ 2. \_\_\_ 3. \_\_\_ 4. \_\_\_)
- 2.8  Position dynamometer 5cm proximal to lateral femoral epicondyle on impaired leg
- 2.9  "When I say "GO" push as hard as you can. READY , set, GO!" PUSH, PUSH, PUSH, PUSH, PUSH, STOP!"
- 2.1  **Impaired leg**  
(1. \_\_\_ 2. \_\_\_ 3. \_\_\_ 4. \_\_\_)
- 3  **Gait Velocity**
- 
- 3.1  Measure out 3 meter distance
- 3.2  Set-up object at 3 meter mark
- 3.3  Clear stopwatch.
- 3.4  "I am going to see how fast you walk. When I say "Go" walk over and touch that object. Do not run."
- 3.5  **READY, Set, GO!"**  
(1. \_\_\_ 2. \_\_\_ 3. \_\_\_)
- 4  **Timed Up and Go**
- 
- 4.1  Set-up folding chair
- 4.2  Seat child in chair, feet flat on floor
- 4.3  "I am going to see how long it takes you to get up from this chair, walk to the object and get back to sitting in this chair . 4.6  (1. \_\_\_ 2. \_\_\_ 3. \_\_\_)
- 4.4  Clear stopwatch.
- 4.5  Set-up folding chair
- 4.5  "When I say "GO", stand up, walk over to the object, touch it and turn around and walk back to the chair and sit down Do not run. Ready, Set, GO!"

## Maintenance Checklist

- 5  **Center of Pressure and Time to Boundary**
- 
- 5.1  Start-up laptop
- 5.2  Power up forceplate
- 5.3  Connect forceplate to laptop
- 5.4  Open Balance Clinic software
- 5.5  Calibrate (zero out) forceplate
- 5.6  Create patient data file
- 5.7  Load Gina's protocol.
- 5.8  Stand child on forceplate. Center feet horizontally and vertically
- 5.9  Using pre-recorded coordinates position feet appropriately on board.
- 5.1  "I am going to see how well you can stand still with your eyes open and closed. Pick something in front of you to look at. What are you looking at?"
- 5.11  Child answers.
- 5.12  "When I say "Go" you are going to stand as still as you can looking at \*blank\*. Ready , Set, GO"
- 5.13  (1. \_\_\_ 2. \_\_\_ 3. \_\_\_)
- 5.14  Save trials individually
- 5.15  "Now we are going to do the same thing with your eyes closed. When I say "Go" close your eyes and don't open them until I say so. Ready, Set, GO, close your eyes"
- 5.16  (1. \_\_\_ 2. \_\_\_ 3. \_\_\_)
- 5.18  "Open your eyes"
- 5.19  Save trials individually
- 5.20  Power down laptop, forceplate.
- 6  **Weight Bearing Symmetry**
- 
- 6.1  Plug in Wii
- 6.2  Set-up Wii sensor bar
- 6.3  Turn on Wii
- 6.4  Import Mii or create Mii
- 6.5  Load WiiFit CD
- 6.6  Enter data as prompted
- 6.7  Turn on Wii balance board
- 6.8  Have child stand on board
- 6.9  Use pre-recorded distances to position feet on WBB
- 6.10  "I am going to see how well you stand still on this board. You need to look at the TV and focus on the green light.
- 6.11  Load WBS test on WiiFit
- 6.12  "Ready, Set, Go"
- 6.13  Power down Wii and balance board

### Maintenance Checklist

7  **Activities Scale for Kids**

7.1  Write child's ID number & date on booklet

*"This is a book that asks you about things that you have done in the past week. You and your parents should read each question and choose the best answer. Circle the answer in the book. Mail it back to me in this envelope when you have finished it."*

9  **Enjoyment Questionnaire**

9.1  Write down child ID number and date on paper

9.2  *"Now I am going to ask you how much you enjoyed playing the games and how hard they were to play. I have three questions to ask you. You can answer the questions by pointing to the face or number that is how you feel or reading the words below"*

9.3  Read question 1

9.4  Child response

9.5  Read question 2

9.6  Child response

9.7  Read question 3

9.8  Child response

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## Vita

Gina C. Siconolfi-Morris, PT, MPT

### I. General Information

Birth date and place: April 21, 1980 Akron, Ohio  
Licensure: Kentucky License: 005025 2006- present  
New York License: 025377-1 2003- present  
Maiden Name: Gina Doell Siconolfi

### II. Education

2007 Graduate Certificate in Developmental Disabilities: University of Kentucky. Lexington, KY  
2003 Master of Physical Therapy: University of New England. Biddeford, ME  
2002 Bachelor of Health Sciences: University of New England. Biddeford, ME

### III. Professional Experience

#### Therapist Experience

11/2010- 01/2011 Motion analysis laboratory physical therapist: Shriner's Hospital for Children. Lexington, KY  
03/2009- 05/2009 Pediatric physical therapist: On the Move. Lexington, KY  
06/2007- 10/2007 Pediatric physical therapist: University of Kentucky. Lexington, KY  
10/2006- 03/2007 Physical therapist: Horn Richardson and Associates in Rehabilitation. Lexington, KY  
09/2003- 07/2006 Pediatric physical therapist and service coordinator: Bay Cove Human Services Early Intervention Division. Dorchester, MA

#### Teaching Experience

09/2012-10/2012 Guest lecturer and laboratory instructor: PT655 Neuromotor Development & Physical Therapy Management of the Pediatric Client, University of Kentucky. Lexington, KY  
08/2011- 10/2011 Guest lecturer and lead laboratory instructor: PT655 Neuromotor Development & Physical Therapy Management of the Pediatric Client, University of Kentucky. Lexington, KY  
01/2010- 02/2010 Teaching assistant: PT686 Physical Therapy Electives: Pediatric Physical Therapy, University of Kentucky. Lexington, KY  
02/2010 Guest lecturer: PT654 Motor Control Theory and Intervention, University of Kentucky. Lexington, KY  
Guest facilitator: PT860 Diagnosis and Management of the Complex Patient  
08/2007- 10/2009 Teaching and laboratory assistant: PT655 Neuromotor Development & Physical Therapy Management of the Pediatric Client, University of Kentucky. Lexington, KY

#### IV. Honors

- 2006- 2007 Kentucky Graduate Scholarship, University of Kentucky  
2001- 2002 Dean's List, University of New England

#### V. Presentations

##### National (Peer Reviewed)

- 2009 American College of Sports Medicine Annual Conference. Seattle, WA  
Oral: *Reliability of the Sensory Organization Test in Typically Developing Children Aged 4 to 10 Years.* Siconolfi-Morris G, Mattacola CG, Effgen SK.  
2008 American Physical Therapy Association Annual Conference. San Antonio, TX  
Oral: *Effect of Changing Intensity of Physical Therapy on the Acquisition of Gross Motor Skills in Young Children With Disabilities.* Effgen SK, Siconolfi-Morris G.  
American Academy of Cerebral Palsy and Developmental Medicine Annual Conference. Atlanta, GA  
Poster: *Effect of Changing Intensity of Physical Therapy on the Acquisition of Gross Motor Skills in Young Children With Disabilities.* Effgen SK, Siconolfi-Morris G.

##### Local (Peer Reviewed)

- 2009 Center for Clinical and Translational Science Spring Conference. Lexington, KY  
Poster: *Intra-day Reliability and Learning Effects of the Sensory Organization Test in Typically Developing Children.* Siconolfi-Morris G, Mattacola CG.

##### Local (Invited)

- 2005 Reflexes of Development. In-service for staff at Bay Cove Early Intervention, Dorchester, MA  
2004 Gross Motor Development and Stimulation during Toddler Group. In-service for staff at Bay Cove Early Intervention, Dorchester, MA

#### VI. Publications

##### Published Abstracts

- Siconolfi-Morris GC, Mattacola CG, Effgen SK. Reliability of the Sensory Organization Test in Typically Developing Children Aged 4 to 10 Years. *Medicine and Science in Sports and Exercise* 2009; 41(5S): 147.  
Effgen SK, Siconolfi-Morris G. Effect of Changing Intensity of Physical Therapy on the Acquisition of Gross Motor Skills in Young Children With Disabilities. *Developmental Medicine and Child Neurology* 2008; 50(S4): 47.

##### Invited (non-refereed)

- Siconolfi-Morris GC. Creating family-centered fitness interventions in your clinic. *HPA Resource* 2011; 11(3): 15.



Book Sections

Siconolfi-Morris GC. Lower extremity ROM ranges or means from birth to 3 years and mandibular and spinal range of motion mean values. In: Effgen SK, ed. *Meeting the Physical Therapy Needs of Children, 2<sup>nd</sup> ed.* Philadelphia: F.A. Davis; 2013: 189-192.