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A Biomedical Analysis of the Walking Patterns of Blind Individuals Who Consistently Veer

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A BIOMECHANICAL ANALYSIS OF THE WALKING PATTERNS OF BLIND INDIVIDUALS WHO CONSISTENTLY VEER

by

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The problem of the study was to describe the gait patterns of congenitally blind adults who veer when attempting to walk in a straight path. Specifically, the investigation compared the walking patterns of blind subjects to the walking patterns of sighted subjects as described in the literature and compared the symmetry between the right and left sides of the body. Results indicated: (a) no significant difference among the three trials for pelvic rotation, foot position at foot plant, knee angle, shoulder rotation, vertical displacement of the center of gravity, ankle angle, thigh angle, foot displacement, left step length, and trunk inclination; (b) a significant difference among the trials for medial/lateral displacement of the center of gravity or right step length; (c) a significant difference between the right and left legs for the ankle angle and thigh angle; (d) a significant difference among the four positions for pelvic rotation, ankle angle, knee angle, and thigh angle; (e) a significant difference in the first order interaction effect, leg by position, was found for pelvic rotation; (f) no significant difference between the right and left legs for foot angle; and (g) a significant difference between the right and left legs for step length. The conclusions were: (a) symmetry was not achieved for all the dependent variables between the right and left side of the body in trials that the subjects veered, and (b) blind walk gait and normal walk gait are more similar than dissimilar.

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CHAPTER I

INTRODUCTION

When vision is not used as sensory input, human gait patterns are characterized by veering to the right or left when attempting to progress in a straight line. This phenomenon has been a factor in situations where sighted people are lost in a forest and walk in a spiral path rather than in straight lines or when attention focuses on something other than the task of walking. For blind individuals, a veering gait pattern is associated with: (a) risky situations that may endanger the walker, (b) greater distance traveled, and (c) a hindrance to learning spatial relationships between objects (Guth & LaDuke, 1994). The literature revealed four ways to reduce the veering tendency for blind individuals: (1) auditory processing of environmental information; (2) visual guidance by a human or a guide dog; (3) information in the environment such as talking signs; and (4) increased walking speed (Guth & LaDuke, 1994). However, according to orientation and mobility instructors the veering tendency has not been completely eliminated using these techniques. Guth and La Duke (1994) suggested that gait patterns of the blind need to be biomechanically evaluated in order to learn how the mechanics contribute to the veering tendency.

Problem Statement

The problem of the study was to describe the gait patterns of congenitally blind adults who veer when attempting to walk in a straight path. Specifically, the investigation compared the walking patterns of blind subjects to the walking patterns of sighted subjects as described in the literature and compared the symmetry between the right and left sides of the body.

Purpose of the Study

Researchers have studied veering, a change in direction or course from an intended straight path, of blind and sighted individuals in an attempt to understand the underlying causes of the veering tendency. Researchers have evaluated leg length, arm length, and walking speed in blind and sighted individuals as possible explanations of the veering tendency. The results of these studies have not been of great benefit to the orientation and mobility instructor in correcting the veering in blind individuals (Guth & LaDuke, 1994). Extensive research has been conducted for sighted individuals' mechanics of the walk gait. However, there are few studies available that describe the gait of blind individuals or compare the gait of blind and sighted individuals. Guth and La Duke (1994) concluded, after writing a literature review on blind gait and veering, that future research needs to address the mechanics of gait patterns of the blind. An accurate description of the gait for individuals who veer rather than an explanation of veering may begin to answer the question, "Why do blind people veer?"

Delimitations

The study was delimited to the following:

1. Subjects were male volunteers who were congenitally blind, between 18 and 25 years of age, and attending Western Michigan University, Kalamazoo.

2. Subjects were all known to consistently veer to the right or left when attempting to walk in a straight path.

3. A three-dimensional biomechanical analysis utilizing the Peak Motus System, Peak Performance Technology, Inc., Inglewood, CO, was used to collect and calculate the variables measured in the study.

4. Subjects were videotaped while walking to a metronome set at a cadence of 100 bpm.

5. Five trials of unassisted walking using a cane were recorded for analysis.

Limitations

The limitations that may affect the interpretations of the results are listed below:

1. The walking patterns in a lab setting may not be the same as the patterns used in daily walking.

2. The small sample size that was opportunistically derived may affect the external validity of the study.

3. The results of this study may not adequately describe female gait patterns.

Assumptions

The assumptions for the study were:

1. Subjects walked at a set speed controlled by a 100 bpm metronome during each trial.

2. All test instruments in the study were reliable and valid.

3. The normal walking patterns evaluated were derived from the subjects' experience walking as a congenitally blind individual.

Research Hypotheses

The expected results of this study included the following:

1. Asymmetry, for all the dependent variables, was expected between the right and left sides of the body in the trials where subjects veered.

2. Symmetry, for all the dependent variables, was expected between the right and left sides of the body in the trials where subjects did not veer.

3. The normal gait patterns of sighted individuals as described in the literature was expected to be more similar than dissimilar compared to the subjects in the study.

Definitions of Terms

The following terms are important to the understanding of this study:

1. *Congenital:* Existing since birth.

2. *Braking Phase:* The period of time in a gait cycle that begins with heel strike and ends at foot flat.

3. *Foot Flat*: The point in the gait cycle where both the heel and toes make contact with the floor. This point marks the end of the braking phase and the beginning of the mid-stance phase.

4. *Heel Off:* This is the point in a gait cycle where the heel comes off the floor. This point marks the end of the mid-stance phase and the beginning of the propulsion phase.

5. *Heel Strike:* This is the point in a gait cycle where the heel makes its initial contact with the floor. Heel strike marks the end of the swing phase and the beginning of the stance and braking phase.

6. *Mid-stance Phase*: This period of time begins at foot flat and ends at heel off. This phase is part of the stance phase.

7. *Propulsion Phase:* This period of time begins at heel off and ends at toe off. This phase is part of the stance phase.

8. *Stance Phase:* This phase represents the duration of time in which the foot remains in contact with the ground. The braking, mid-stance, and propulsion phases make up the stance phase.

9. *Step Length*: The horizontal distance between opposite heel strikes of the feet's center of gravity.

10. *Swing Phase:* This phase represents the duration in which the foot is off the ground. The phase begins after toe off and ends before heel strike.

11. *Toe Off* : The point in a gait cycle where the toes leave the floor. This point ends the stance and propulsion phases and begins the swing phase.

12. *Veer:* To gradually change the course of direction from an intended straight path.

CHAPTER II

REVIEW OF LITERATURE

The problem of the study was to describe the gait patterns of congenitally blind adults who veer when attempting to walk in a straight path. Specifically, the investigation compared the walking patterns of blind subjects to the walking patterns of sighted subjects as described in the literature and compared the symmetry between the right and left sides of the body. The review of literature to support the problem was organized into the following areas: (a) veering, (b) normal walk gait patterns, (c) filming technique, and (d) summary.

Veering of the Blind

Veering is a gradual change in one's course or direction. There is a tendency in all mobile organisms to circle in a spiral form. This happens when walking, running, swimming, rowing, and even driving automobiles (Lund, 1930). Guth and LaDuke (1994) wrote a review of the literature that listed negative aspects associated with blind individuals who veer. These aspects included walking into traffic or other dangerous areas, walking farther than intended, and hindering the learning of spatial relationships. Veering can be decreased by the following: (a) the use of environmental sounds; (b) the use of human guidance, guide dogs, or electronic devices; (c) the use of talking signs; and (d) possibly increasing walking speed. Since 1930, researchers have studied the veering gait of blind people. A chronological review of this research is presented below.

Lund (1930) studied physical asymmetries and gait disorientation which comes from direct observation of pathological studies. The subjects, $N = 125$, walked forward, backward, and over arcs. The subjects, psychology students, were evaluated as they walked blindfolded across a green turf. The results did not provide evidence correlating functional asymmetry to structural asymmetry.

Rouse and Worchel (1955) evaluated the veering tendency in 18 blind subjects (11 males and 7 females). Subjects completed four walking conditions: (1) blindfolded, (2) blindfolded with a hood over the head and shoulders, (3) blindfolded with ear plugs, and (4) blindfolded with hood and ear plugs. Subjects walked distances of 100 ft, 200 ft, and 300 ft. Each subject performed the experiment under the four conditions mentioned above. Following each trial, the subjects were asked if they thought that they had walked straight and they generally believed that they had. The results showed that for 100 ft there was a deviation of 8.89° to 13.22° from the straight path. For 200 ft the deviation was 15.06° to 21.00°. Finally, for 300 ft the deviation was 22.14° to 25.28°. The results showed that increasing the distance walked significantly increased the deviation from the intended path. No differences in veering were found between the four conditions. Therefore, environmental auditory and facial cues did not impact the veering tendency.

Cratty (1967) also evaluated veering while walking without vision. This study utilized 164 blind subjects from the Los Angeles area. Subjects were either congenitally totally blind, adventitiously totally blind, or partially blind. The subjects were not allowed to use dogs, canes, or other means to assist travel. During the study the subjects wore blindfolds, ear plugs, and hoods to cut down on environmental cues as they walked across a large athletic field. The subjects started at a midpoint on the athletic field, were led 5 steps, and then attempted to continue to walk in a straight path. Leg length was measured to the nearest ¼ of an inch, from the hip bone to the floor. The direction of the veer was predictable, but the degree of veer between the trials was moderately correlated, $r = 0.4$ to 0.5 depending on the group. The subjects that veered more than two times to the left, veered significantly more than those who veered right. Veering was not found to be related to head torsion, leg length, hand dominance, or leg dominance. The subjects who lost vision at an older age veered more. The subjects who were blind since birth veered less than the adventitiously blind. The sighted subjects veered significantly more than their matched group of blind subjects (matched by age, gender, education level, height, and weight). There was not a significant difference between the totally blind and partially blind subjects. The subjects who were blind for 6 to 10 years veered more than did the subjects who were blind for 20 or more years.

Harris (1967) measured anxiety as it related to the veering tendency. Anxiety was defined as a generalized fear or foreboding. The Taylor's Manifest Anxiety Test was administered to determine the anxiety level of the subjects before the experiment. Two of the subjects were considered to have high anxiety. The subjects were evaluated on a grassy athletic field where they walked two distances: (1) 100 m, and (2) 200 m. Each subject was blindfolded before arriving, earplugs were inserted, and hoods were used to reduce light, sound, and wind cues. Eight trials were completed. The low anxiety group veered less and walked faster than the high anxiety group. The high anxiety subjects walked an average of 1.02 fps slower than the low anxiety subjects. There was a tendency for subjects to veer less during the 100 m and more during the 200 m walks. This led the researchers to believe that the subjects were not completely focused on the task of walking forward in a straight line, due to anxiety. A moderate correlation ($r = .51$) was reported between walking speed and anxiety.

Elliot (1987) studied the effects of practice and walking speed to estimate distance traveled and he also measured veer in his study. There were 12 males and 8 females divided into two groups: feedback and no feedback. There were five targets positioned 4, 6, 8, 10, and 12 m from the subjects' starting location in an activity room. The feedback group completed 20 practice trials, with their eyes closed walking toward target distances of 6 and 10 m. For half of the practice trials, the subjects were told to walk fast, and the remaining half they were told to walk at a normal speed. The no feedback group had the identical number of trials, but they were not permitted to open their eyes. Each subject completed the same 90 experimental trials. The design consisted of two groups (feedback and no feedback), two walking speeds (fast and normal), three distances (4, 8, and 12 m), and three delays (0, 2, and 4 s). Delay is the time subjects waited before they started walking. The results indicated that the subjects overwalked the targets placed at 8 to 12 m. Practicing with the eyes closed appeared to increase the ability to reach the target. The direction of veering left or right was not dependent upon speed or delay, although delays impacted walking speed and distance, and 2 s delays may be useful in controlling rapid manual movements. The results showed little discrepancy between subjects at the 4 m distance, but 8 and 12 m showed an increasing overshot in walking the longer distances.

Cicinelli (1989) studied the effects of preview (seeing the destination before starting to walk) and walking speed on the magnitude and direction of veering. All subjects were sighted. Each subject wore headphones to reduce environmental sound. On the top of the headphones was a light that was filmed to detect movement location. The subjects practiced walking at slow, normal, and fast speeds until they felt comfortable. There was a camera in front of the subject and another at a 90°

angle to the side. The subjects aligned their body against the wall then walked unaided straight ahead. After 14 m the subjects were told to stop. No feedback was given. As the subjects walking speed increased their veering decreased. The second study involved two speeds, normal and slow. The subjects were blindfolded and given 10 minutes to adjust to the environment. After the adjustment period, each subject walked across the gym and was led back to the starting point. Subjects were not allowed to lift the blindfold. There were three repetitions of the two speeds. The results of the experiment suggested that walking speed influenced the magnitude of an individual's veer.

Rieser, Ashmead, Talor, and Youngquist (1990) assessed the accuracy of individuals' visual-motor coordination and evaluated the degree to which visual perception contributed to veer. The first half of the two-part experiment looked at the visual perception of distance. The subjects stood beside one experimenter, and the other experimenter stood directly ahead of the subject. The subject chose the midpoint then attempted to walk to the midpoint, across a flat, grassy lawn that was open to the sun. The target distances were 6, 12, 18, and 24 m for both experiments. There was no evidence of systematic veering error. The average variable errors were small for each subject's six trials. Subjects' perceptions of the veer were correct 52% of the time, which is what would be expected by chance. The second portion of the experiment assessed accuracy and precision without vision while walking toward a previously viewed target. There were 10 graduate students and staff from the psychology department who walked outdoors using a long cane and earphones to block their use of sound cues. The subjects walked the targeted distance five times under three conditions (normal, delay, and fast). The stopwatch was started when the subjects' eyes were closed and they began walking from the target. It was stopped when the subjects ceased walking. There were 15 practice trials allowing the subjects to open their eyes and see the error they made. A total of 165 trials were completed for each subject within 30 min. The results indicated that the variable error was not influenced by time. There was also a significant difference in accuracy between the delay and normal conditions compared to the fast instructions. However, subjects only veered approximately 20 cm and there was no apparent pattern to their veer. This may be due to the relatively short distance that subjects walked in comparison to subjects in other veering research studies.

Uetake (1992) looked at the ability of individuals to walk in a straight line. There were 10 Japanese men between the ages of 18–45 years without a history of lower limb problems. The subjects' feet were soaked in red ink and had pedal switches beneath their heels while they walked on white paper. The pedal switches were made of two fine wires separated by rubber mats containing fine grained iron which was compressed under body weight to permit current to flow from one wire to the other. They were told to walk at a normal speed for 60 m. After practicing, subjects started in the middle at the end of the room and walked at a normal speed. Steps 5 through 68 were analyzed. The researchers concluded that an individual cannot walk in a straight line. An increase in the foot angle was associated with lateral body balance. The foot angle of the subjects was significantly different for 13 of the 20 subjects. Specifically, 10 subjects had a greater right foot angle than left foot angle. The results indicated subjects had gait asymmetry.

Guth and LaDuke (1995) evaluated the veering tendency (gradual change in direction) of blind subjects. The causes of blindness varied. Three traveled with a cane and one with a guide dog. There were three 15-trial sessions to identify the spatial characteristics. Subjects were filmed by a video camera operator who followed them as they walked across a grid that was marked on a tennis court. Subjects wore padded earphones and traveled without canes. To start, they stood over the center line to square off and were told to walk at a comfortable, normal pace. The path was 25 m. The spatial characteristics measured were different between and within subjects. Some subjects veered consistently to the left and some to the right. Still others were inconsistent, sometimes veering to the left and sometimes to the right within the same test session. Some subjects were much more variable from trial to trial than others with the same general veering direction.

Guth and LaDuke (1994) and Knutzen, Hamill, and Bates (1985) suggested future research involving cinematography to enable researchers to describe the characteristics of an individual who displays a veering tendency. A two- or three-dimensional view would be ideal to digitize every joint on the body. The orientation and mobility instructor of blind subjects would benefit from the knowledge obtained from the project described. The description could help the orientation and mobility instructor to adjust the biomechanics so the blind individual would be able to walk a straighter path. The descriptive study would need to note the spatial characteristics of individuals with the veering tendency so that these characteristics can be described across subjects. The orientation and mobility instructor could use this information to attempt to intervene and influence the relevant biomechanics which may, in turn, reduce a blind student's tendency to veer.

Normal Walk Gait Patterns

Walking occurs in a linear direction, though it involves angular motion of the lower extremities at the hip, knee, and ankle. Locomotion is a functional and independent movement. During walking the body is supported in an upright position, balance is maintained, and the stepping movement is most generally forward (Murray, 1967). The walking cycle includes consecutive foot contacts with a floor. Four events in the stance phase of a walking cycle are heel strike, foot flat, heel off, and toe off. Heel strike is the point in the gait cycle at which the heel makes contact with the floor. Foot flat is the point in the gait cycle at which both the heel and toes make contact with the floor. Heel off is the point at which the heel leaves the floor. Toe off is the point in the gait cycle at which the toe leaves the floor.

The gait cycle is composed of a stance and a swing phase. The stance phase is 60% of the stride time and the swing phase is 40% of the stride time (Nordin & Frankel, 1989). The weight-bearing leg must provide restraint, support, and propulsion forward (Murray, 1967). The stance phase is comprised of three subphases: braking, midstance, and propulsion. The stance phase and braking subphase begin at heel strike, which is marked by a slight deceleration of the motion. The midstance subphase begins at foot flat and ends at heel off. The propulsion subphase begins at heel off and ends at toe off and is the final subphase of the stance phase.

The swing phase is composed of three subphases: acceleration, toe clearance, and deceleration. The swing phase and acceleration subphase begins at toe off and ends when the toe dorsalflexes to clear the floor as the leg swings through. The second subphase, toe clearance, begins at toe dorsalflexion and ends when the toe passes over the ground. The deceleration subphase begins after the toe clears the ground and ends at heel strike, marking the end of the swing phase.

Normal walking is characterized by a wide range in speed, smooth forward motion, rhythm in the steps, and duration of the walking cycle (Murray, 1967). Thus, each individual has unique characteristics in his or her walking cycle. Kairento and

Hellen (1979) supported this by indicating differences in individuals for velocity, acceleration, and moments. The purpose of Iida and Yamamuro's (1987) study was to determine the normal walk gait variations. The walking velocity was constant and the body was regarded as a multi-segmented model. An increase in walking speed increases step length, hip flexion, and ankle extension of the rear extremities. The toeing out of an individual widens the base of support, mainly because objects with wider bases are more stable than those with narrow bases. There is shorter stride length with increased outward toeing (Murray, 1967). The step width is directly related to the stability of the body of an individual while walking. Although there are variations among individuals that characterize their walk gait, there were no statistically significant differences between the left and right side (Kairento & Hellen, 1979). Within the walking cycle there are two single-leg supports (right and left), and two double-leg supports. As mentioned earlier, during each stride the foot alternates between the support phase and the swing phase. Table 1 is a summary of the kinematic values found in the literature for these phases for sighted individuals.

The thorax and pelvis show a transverse rotation. The rotation is upward and clockwise and then downward and counterclockwise (Murray, Drought, & Kory, 1964). The pelvis rotates right and left in the line of progression (Saunders, Inman, & Eberhart, 1953). The shoulders move forward at heel strike and then move back at the swing phase. The elbow movement is similar. At heel strike the elbow is flexed and during the swing phase the elbow extends.

The body's center of gravity follows three pathways—vertical, lateral, and forward—when walking. There are two peaks and two valleys in the vertical pathway of the walking cycle, two lateral deflections in the lateral pathway, and the forward pathway is smooth (linear).

Table 1

Kinematic Values for Normal Walking Gait

Attributes			
Variable	Phase	Value	Source
Temporal			
Stance	HS	0%	Nordin & Frankel, 1989
	FF	15%	Nordin & Frankel, 1989
	HR	30%	Nordin & Frankel, 1989
	PO	45%	Nordin & Frankel, 1989
	TO	60%	Nordin & Frankel, 1989
Swing	Acceleration	70%	Nordin & Frankel, 1989
	TC	85%	Nordin & Frankel, 1989
	Deceleration	100%	Nordin & Frankel, 1989
Linear Kinematics			
Avg. speed		151±20cm/sec	Murray et al., 1964
		70 steps/min	Adrian & Cooper, 1989
Duration		1.06±0.09sec	Murray et al., 1964
Cadence		113 steps/min	Murray et al., 1964
Stride length		156±13 cm	Murray et al., 1964
Stride width		7.7±3.5 cm	Murray, 1967
Angular Kinematics			
Pelvis	Stance	4° int. and ext. rot.	Saunders et al., 1953
	Stance	5° downward tilt	Saunders et al., 1953
Knee	HS	5 to 8° flexion	Nordin & Frankel, 1989
	FF	5 to 15° flexion	Adrian & Cooper, 1989
	Support	17 to 20° flexion	Kettelkamp, Johnson,
	Swing	60 to 88° flexion	Smidt, Chao, & Walker,
		12 to 17° int. and ext. rot.	1970, and Lafortune, Cavanagh, Sommer, & Kalenak, 1992
Ankle	HS	80° dorsiflexion	Adrian & Cooper, 1989
	FF	90° neutral	Adrian & Cooper, 1989
	HO	85° dorsiflexion	Adrian & Cooper, 1989
	TO	105° plantar flexion	Adrian & Cooper, 1989
Foot		6.3±5.7 degrees	Murray et al., 1964

Filming Technique

The study of human movement has improved due to recent technology advances. The walk gait of humans has been researched in laboratory studies for various medical and bioengineering studies. These studies have utilized high-speed filming and computer analysis of body motion to determine characteristics of the normal walking cycle.

Humans have been filmed at 50–120 fps in many different field and laboratory settings. The recorded film was changed to a quantitative form. The anatomical landmarks of the body are projected onto a grid. Each point is recorded and digitized for storage, processing, and statistical analysis. The data analyzed include angle of joints, velocity of body parts acceleration, displacement, and length of stride (Hennessy, Dixon, & Simon, 1984).

Summary

In conclusion, the explanation for veering in the blind has not been adequately explained. There have been veering studies related to anxiety, speed, without sight, and without sound. However, the cause of veer in individuals has yet to be explained. There is sufficient research on the normal walk gait of sighted subjects. While studies of the gait patterns of the congenitally blind adults are limited, those which have been completed gave valuable information regarding to the logistics of doing such research.

CHAPTER III

METHODS AND PROCEDURES

The problem of the study was to describe the gait patterns of congenitally blind adults who veer when attempting to walk in a straight path. Specifically, the investigation compared the walking patterns of blind subjects to the walking patterns of sighted subjects as described in the literature and compared the symmetry between the right and left sides of the body. This chapter described the procedures and methods that were followed in conducting this study. The chapter is divided into the following sections: (a) subjects, (b) instrumentation, (c) filming, (d) video digitizing, and (e) research design.

Subjects

Nine congenitally blind individuals who veer when walking served as subjects for this study. The direction of veer was determined by positioning the subjects in the center of the aerobics room (Student Recreation Center of Western Michigan University, Kalamazoo). Subjects wore a blindfold, Walkman, and ear muffs while walking with the aid of their canes for 25 m or until they were told to stop or were tapped on the shoulder. Subjects hips and shoulders were aligned parallel to the wall, guided for the first three steps, and then continued to walk 25 m unless they veered significantly. This procedure was repeated 10 times, recording the direction, right, left, or no veer for each trial (see data in Appendix A). Subjects who consistently veered to the right or the left over 8 of the 10 trials were selected as subjects for the study. Volunteers were from Western Michigan University, Kalamazoo. Prior to participation all volunteers signed a consent form (Appendix B). The subjects were males between the ages of 18–24 years. This study was approved by Western Michigan University Human Subjects Institutional Review Board (Appendix C).

Instrumentation

A three-dimensional video analysis was used to evaluate the walking patterns. The cameras used were a Panasonic WV-D5100HS video camera and a Panasonic AG 450 (Panasonic, Secaucus, NJ). The cameras were placed at 45° angles to the sagittal plane of the subject's walking path and perpendicular to one another. The video tapes used were Maxell XR-S ST160 S-VHS. The Peak Motus System, Peak Performance Technology, Inc., Englewood, CO, was used to collect data, synchronize the cameras, and calculate the dependent variables measured in the study.

Filming

The data collection took place in the Biomechanics Lab in the Student Recreation Center, Western Michigan University, Kalamazoo. The subjects wore dark shorts and t-shirts. Each subject completed five trials of walking 10–15 steps in a barrier free area. Subjects used their canes to assist them during the five trials. Guide dogs or human assistance was not permitted.

Prior to collecting data the subjects were oriented to the walking area. This orientation period was a guided tour of the test area lasting about 5 minutes or until the subjects felt comfortable. After the orientation period the subjects wore a blindfold, Walkman, and ear muffs. A trial consisted of: (a) leading the subject to the starting point on the floor, (b) positioning the feet and shoulders perpendicular to the intended walking path, (c) instructing the subject to begin walking in a straight line, and (d) tapping on the subject's shoulder and verbally instructing the subject to stop walking. This procedure was repeated for three trials.

Video Digitizing

Following data collection the digitizing process began. It was necessary to digitize the distal end of the finger and shoe; the center of the ankle, knee, hip, shoulder, elbow and wrist joints; top of the sternal notch and head; and midline of pelvic bone. The analysis began two frames before right foot heel strike and ended two frames after the next right foot heel strike. The motion was divided into two phases: (1) stance and (2) swing. The stance phase began at heel strike and ended before toe off. The stance phase was subdivided into three phases: (1) braking phase, (2) mid-stance phase, and (3) propulsion phase. The swing phase began at toe off and ended before right foot heel strike. The swing phase was divided into three parts: (1) initial swing, (2) mid swing, and (3) terminal swing. The raw digitized coordinates were smoothed (conditioned) with the Butterworth filter set at 6 Hz. The dependent variables were then calculated. The software used relative weights and segment center of gravity locations to calculate the coordinates of each segment and the total body's center of gravity.

Research Design

Each subject performed three trials. An ANOVA was calculated to determine the consistency among the trials. If there was no significant difference among the trials then the mean of the three trials was used in the statistical analysis for testing the research hypotheses. If there was a significant difference among the trials then trials were used as a variable in the final statistical analysis. Statistics, *t* tests or ANOVAs, were calculated to test for symmetry between the right and left extremities.

The dependent variables of the study included:

1. *Pelvic rotation*: The rotation of the pelvis in the transverse plane. Rotation to the right was measured as a positive angle and rotation to the left was measured as a negative angle.

2. *Foot position at foot plant*: The angle of the foot (longitudinal axis) with respect to the forward motion. An angle of 0° indicated that the feet were parallel with the direction of the motion. A negative angle indicated that the feet were medially rotated and a positive angle indicated that the feet were laterally rotated.

3. *Knee angle*: The angle of the knee in the sagittal plane was the angular displacement between the longitudinal axis of the thigh and the longitudinal axis of the shank. This angle was measured on the posterior side of the thigh and shank.

4. *Shoulder rotation:* The rotation of the shoulders in the transverse plane. Rotation to the right was measured as a positive angle and rotation to the left was measured as a negative angle.

5. *Center of gravity displacement:* Displacement of the COG in both the vertical and lateral directions were calculated.

6. *Ankle angle:* The movement of the ankle in the sagittal plane was measured by the angle formed between a longitudinal axis passing through the shank and one passing through the foot. Plantar flexion was indicated as a negative angle and dorsiflexion as a positive angle. The angle was measured on the anterior side of the shank and foot.

7. *Thigh angle:* The angle formed between the longitudinal axis of the thigh and a horizontal passing through the hip joint. The angle was measured on the anterior side of the body. Hip flexion was indicated by a positive angle and hip extension by a negative angle.

8. *Step lengths:* The horizontal distance between successive heel strikes, right foot to left and left to right.

9. *Right / left foot displacement:* The lateral displacement between the center of gravities of the feet at the point of foot flat.

10. *Trunk inclination:* The angle formed by the longitudinal axis of the trunk and a vertical line passing through the midpoint of the hip joints in a sagittal plane. A positive angle indicated forward inclination and a negative angle indicated backward inclination.

CHAPTER IV

RESULTS AND DISCUSSION

Introduction

The problem of the study was to describe the gait patterns of congenitally blind adults who veer when attempting to walk in a straight path. Specifically, the investigation compared the walking patterns of blind subjects to the walking patterns of sighted subjects as described in the literature and compared the symmetry between the right and left sides of the body. In this chapter, the results are presented and discussed in the following order: (a) Angular Kinematics, (b) Symmetry Between Limbs, and (c) Displacement. The discussion is presented in the following order: (a) Trial Consistency, (b) Veering Tendency and Leg Symmetry, and (c) Kinematic Comparison of Blind Gait and Normal Gait.

Results

The study evaluated three walking trials for 9 subjects. During the three trials, 8 subjects veered to the right across the trials. Since the number of subjects in this study was small, the measurements for the subject who veered to the left were converted to make them congruent with a right veer response. This study consisted of 10 kinematic dependent variables: (1) pelvic rotation, (2) foot position at foot plant, (3) knee angle, (4) shoulder rotation, (5) center of gravity displacement,

(6) ankle angle, (7) thigh angle, (8) step lengths, (9) right/left foot displacement, and (10) trunk inclination.

The first step in data analysis was to examine trial consistency for all of the dependent variables. The ANOVA tables for trial consistency can be found in Appendix D. No significant differences were found among the three trials for any of the dependent variables except medial/lateral displacement of the center of gravity, $F(2, 16) = 8.96, p = .00$, and right step length $F(2, 16) = 6.52, p = .01$. The means for medial/lateral displacement for Trials 1, 2, and 3 were 0.067 m, 0.081 m, and 0.087 m, respectively. The means for the right step length for Trials 1, 2, and 3 were 0.67 m, 0.68 m, and 0.71 m. Therefore, subjects' degree of veer was different from trial to trial no consistent degree of veer was apparent within subjects. Right step length also varied within subjects while left step length indicated no significant difference. The results that follow were calculated using the mean of the three trials. Each variable is presented below.

Angular Kinematics

A randomized block factorial ANOVA with two research variables, leg with two levels, right and left, and position with four levels, heel strike, foot flat, heel off, and toe off, were calculated for each angle.

Pelvic Rotation

The ANOVA summary for pelvic rotation is presented in Table 2. The results were as follows:

1. A significant difference was found among the subjects, $F(8, 56) = 20.72$, $p < .05$.

2. No significant difference was found between the right and left legs for pelvic rotation, $F(1, 56) = 0.69, p > .05$. The means for the right and left legs were 93.63° and 94.09°, respectively.

3. A significant difference was found among the four positions for pelvic rotation, $F(3, 56) = 4.34, p < .05$. The means for the positions were 94.21°, 92.74°, 93.16° and 95.34° for the heel strike, foot flat, heel off, and toe off positions, respectively.

4. The first order interaction effect leg by position was significant, $F(3, 56) = 6.73, p < .05$.

Table 2

ANOVA Summary Table for Pelvic Rotation

Source	*SS*	*df*	*MS*	*F*
Subject	928.30	8	116.04	20.72*
Leg (L)	3.84	1	3.84	.69
Position (P)	72.93	3	24.31	4.34*
L × P	112.98	3	37.66	6.73*
Residual	313.61	56	5.60	

*Significant at the .05 level.

<u>Shoulder Rotation</u>

The ANOVA summary for shoulder rotation is presented in Table 3. The results were as follows:

1. A significant difference was found among the subjects, $F(8, 56) = 100.75, p < .05$.

2. No significant difference was found between the right and left legs for shoulder rotation, $F(1, 56) = 0.081$, $p > .05$. The means for the right and left legs were 91.36° and 91.30°, respectively.

3. No significant difference was found among the four positions for shoulder rotation, $F(3, 56) = 0.23$, $p > .05$. The mean for the positions were 91.18°, 91.37°, 91.35°, and 91.42° for the heel strike, foot flat, heel off, and toe off positions, respectively.

4. The first order interaction effect, leg by position, was significant, $F(3, 56) = 16.86$, $p < .05$.

Table 3

ANOVA Summary Table for Shoulder Rotation

Source	*SS*	*df*	*MS*	*F*
Subject	654.45	8	81.81	100.75*
Leg (L)	.066	1	.066	.081
Position (P)	.54	3	.19	.23
L × P	40.99	3	13.66	16.86*
Residual	45.45	56	.81	

*Significant at the .05 level.

Trunk Inclination

The ANOVA summary for trunk inclination is presented in Table 4. The results were as follows:

1. A significant difference was found among the subjects, $F(8, 56) = 8.67$, $p < .05$.

2. No significant difference was found between the right and left legs for trunk inclination, $F(1, 56) = 0.40$, $p > .05$. The means for the right and left legs were 4.88° and 4.71°, respectively.

3. No significant difference was found among the four positions for trunk inclination, $F(3, 56) = 1.12$, $p > .05$. The mean for the positions were 5.08°, 4.68°, 4.96°, and 4.46° for the heel strike, foot flat, heel off, and toe off positions, respectively.

4. The first order interaction effect, leg by position, was not significant, $F(3, 56) = 1.51$, $p > .05$.

Table 4

ANOVA Summary Table for Trunk Inclination

Source	*SS*	*df*	*MS*	*F*
Subject	86.04	8	10.75	8.67
Leg (L)	.50	1	0.50	0.40
Position (P)	4.183	3	1.39	1.12
L × P	5.61	3	1.87	1.51
Residual	69.32	56	1.24	

*Significant at the .05 level.

<u>Ankle</u>

The ANOVA summary for the ankle is presented in Table 5. The results were as follows:

1. A significant difference was found among the subjects, $F(8, 56) = 7.77$, $p < .05$.

2. A significant difference was found between the right and left legs for the ankle, $F(1, 56) = 8.16, p < .05$. The means for the right and left legs were 97.57° and 100.74°, respectively.

3. A significant difference was found among the four positions for the ankles, $F(3, 56) = 113.10, p < .05$. The mean for the positions were 100.75°, 104.44°, 82.22°, and 109.22° for the heel strike, foot flat, heel off, and toe off positions, respectively.

4. The first order interaction effect, leg by position, was not significant, $F(3, 56) = 1.75, p > .05$.

Table 5

ANOVA Summary Table for Ankle Angles

Source	*SS*	*df*	*MS*	*F*
Subject	1380.18	8	172.52	7.77*
Leg (L)	181.05	1	181.05	8.16*
Position (P)	7532.53	3	2510.84	113.10*
L × P	116.21	3	38.74	1.75
Residual	1242.99	56	22.20	

*Significant at the .05 level.

Knee

The ANOVA summary for the knee angle is presented in Table 6. The results were as follows:

1. No significant difference was found among the subjects, $F(8, 56) = 0.92$, $p > .05$.

2. No significant difference was found between the right and left legs for knees angle, $F(1, 56) = 1.48, p > .05$. The means for the right and left legs were 158.36° and 159.92°, respectively.

3. A significant difference was found among the four positions for knee angle, $F(3, 56) = 254.70, p < .05$. The means positions were 172.11°, 166.15°, 169.66°, and 128.65° for the heel strike, foot flat, heel off, and toe off positions, respectively.

4. The first order interaction effect, leg by position, was not significant, $F(3, 56) = 1.45, p > .05$.

Table 6

ANOVA Summary Table for Knee Angles

Source	*SS*	*df*	*MS*	*F*
Subject	217.47	8	172.52	.92
Leg (L)	43.97	1	43.97	1.48
Position (P)	22632.99	3	7544.33	254.70*
L × P	128.51	3	42.84	1.45
Residual	1658.64	56	29.62	

*Significant at the .05 level.

Thigh

The ANOVA summary for the thighs is presented in Table 7. The results were as follows:

1. No significant difference was found among the subjects, $F(8, 56) = 1.12, p > .05$.

2. A significant difference was found between the right and left legs for thigh angle, $F(1, 56) = 4.56, p < .05$. The means for the right and left legs were 83.48° and 86.11°, respectively.

3. A significant difference was found among the four positions for thigh angle, $F(3, 56) = 143.43, p < .05$. The mean for the positions were 71.76°, 73.91°, 102.97°, and 90.53° for the heel strike, foot flat, heel off, and toe off positions, respectively.

4. The first order interaction effect, leg by position, was not significant, $F(3, 56) = 0.78, p > .05$.

Table 7

ANOVA Summary Table for Thigh Angles

Source	*SS*	*df*	*MS*	*F*
Subject	244.38	8	30.55	1.12
Leg (L)	124.30	1	124.30	4.56*
Position (P)	11729.69	3	3909.90	143.43*
L × P	64.57	3	21.52	0.78
Residual	1526.70	56	27.26	

*Significant at the .05 level.

Symmetry Between Limbs

A dependent *t* test was calculated to determine if the right and left legs were symmetrical or asymmetrical for foot angle and step length. For foot angles no significant difference was found, $t(9) = 1.336, p = .218$. The means for the right and left limbs were 24.22° and 17.67°, respectively. For step length no significant difference was found, $t(9) = -0.089$, $p = .93$. The means for the right and left limbs were 0.669 m and 0.673 m, respectively.

Displacement

Descriptive statistics were calculated to describe center of gravity displacement and horizontal displacement between right and left foot placement. The descriptive statistics are presented in Table 8. The mean and standard deviation were calculated, for vertical center of gravity ($M = 0.078$ and $SD = 0.031$), for medial/lateral center of gravity ($M = 0.088$ and $SD = 0.029$), and for stride width ($M = 0.163$ and $SD = 0.027$).

Table 8

The Means and Standard Deviations for the Vertical Center of Gravity, Medial/Lateral Center of Gravity, and the Stride Width

Subject	Vertical C of G	Med/Lat C of G	Stride Width
S1	.027	.070	.147
S2	.066	.104	.164
S3	.091	.053	.153
S4	.100	.097	.181
S5	.092	.066	.167
S6	.113	.056	.212
S7	.099	.118	.111
S8	.089	.138	.174
S9	.028	.094	.161
M	.078	.088	.163
SD	.031	.029	.027

Discussion

The study involved 9 congenitally blind male subjects from southwest Michigan who veered in a minimum of 8 out of 10 walking trials. Each trial consisted of attempting to walk 25 m in a straight path. All 9 subjects veered; 8 veered to the right and 1 veered to the left. The consistency of the gait patterns across three trials, the symmetry of performance between the right and left legs, and the gait mechanics of the subjects were compared to normal gait. Table 1 describes the mechanics for a normal gait. These data were derived from existing studies.

Trial Consistency

During the trials, all subjects veered. Trial consistency existed for pelvic rotation, foot position at heel strike, knee angle, shoulder rotation, vertical displacement of the center of gravity, ankle angle, thigh angle, foot displacement, left step length, and trunk inclination. However, lateral displacement of the center of gravity and right step length were not consistent across the trials. Right foot step length increased across the trials. The lengths were 0.67 m, 0.68 m, and 0.71 m for Trials 1, 2, and 3, respectively. Lateral displacement of the center of gravity also increased across the trials. Lateral displacement was 0.067 m, 0.081 m, and 0.087 m for the Trials 1, 2, and 3, respectively. If all other variables remained constant, subjects would veer to their right. The consistency across trials for pelvic rotation and shoulder rotation indicated that the veer was not caused by trunk rotation. A possible explanation for an increased veer across trials could be a decreased spatial awareness. Trials were repeated one after the other. Subjects did not have the opportunity to reestablish spatial orientation between trials. While blindfolded, subjects were positioned at the start line by the researcher perpendicular to the linear path they attempted to follow.

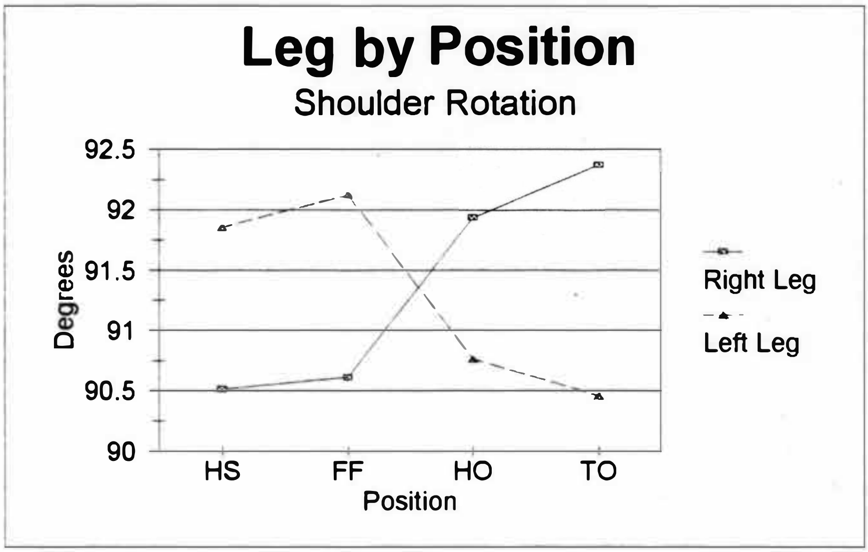
Veering Tendency and Leg Symmetry

There are two possible explanations for a right veer. First, the left leg pushed with an action force back and to the left during each stride resulting in a reaction force that moved the body horizontally forward and to the right (Newton's 3rd Law). This explanation of a right veer would require a strong dominate left leg and/or an improper body position during the push-off phase of the left leg during a stride. Second, a strong right leg push-off caused the left leg to accelerate forward and across the body during each stride. This would require a strong, dominant right leg, a shorter right step, and possibly an outward rotation of the right foot.

Results indicated that the left leg was further forward of the body's center of gravity at initial contact with the ground due to a longer left step length than right step length. A longer left step would result in a greater braking force at left heel strike. This would cause a deceleration during the right step and result in a right veer. Since the left leg must move to the right during a right veer, the movement of the body's center of gravity to the right would cause the left foot to push back and left causing the entire body to move forward and to the right. This would support the first explanation for a right veer.

Results, while not statistically significant, also indicated that in the stance phase of the steps in each stride the right foot was more outwardly rotated than the left foot and the right step was shorter than the left step. The foot angles were 24.22° and 17.67° for the right foot and left foot, respectively. The step length were 0.69 m and 0.66 m for the right step and left step, respectively. Significantly smaller right ankle angles and right thigh angles were detected. This positioned the right foot closer to the center of gravity of the whole body and resulted in a greater potential ground reaction force in the stance phase of the right step than in the left step. In reaction to a greater ground reaction force during the stance phase of the right step, the left leg moved farther forward and across the body and then decelerated in preparation for left foot plant. This would result in a longer left step length than right step length and the body would veer to the right. If this explanation were correct, then pelvic rotation and shoulder rotation would be greater on the left side of the body than the right side. Results indicated that neither pelvic rotation nor shoulder rotation of the right side of the body were significantly different than the left side. However, a significant leg by position interaction effect did occur for both pelvic rotation and shoulder rotation (refer to Figure 1). At heel strike, the left leg rotated the pelvis during the left step more than the right leg did for the right step. This was due to a longer left step. The interaction effect for shoulder rotation indicated that the right shoulder reacted more in opposition to the left leg and left hip rotation than did the left shoulder. This would indicate a difference in right and left step length.

It is possible that veering is caused by a combination of the two explanations presented. Some of the variables measured that would help explain veering were significantly different; others were not. However, actual differences existed in a pattern that would indicate that veering could be caused by a combination of these explanations. The small number of subjects involved in this investigation may have limited the significant findings. Previous investigators Murray et al. (1964) and Kairento and Hellen (1979) stated that no significant mechanical differences should exist between the right and left legs when walking in a straight path. Murray et al. also indicated that an increase in step length is mainly a result of greater hip flexion.



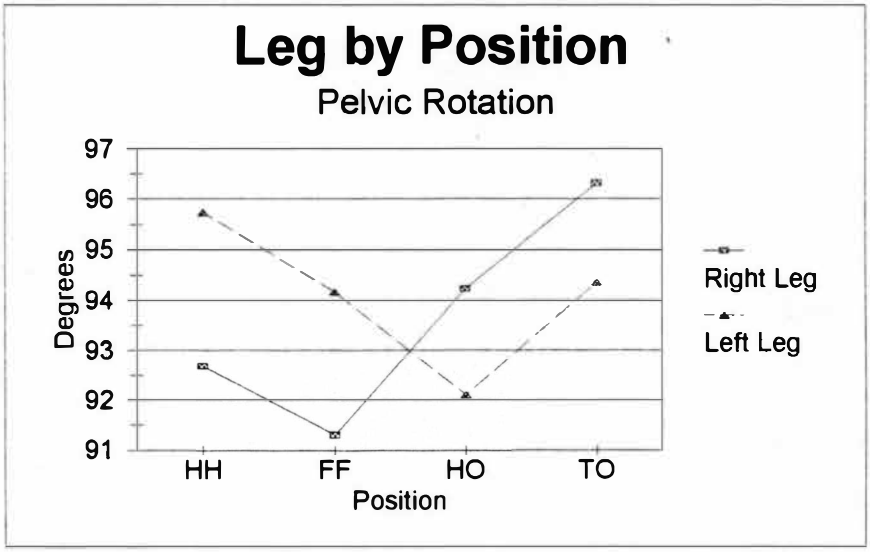


Figure 1. Leg by Position Interaction Effect for Shoulder Rotation and Pelvic Rotation.

In this investigation, greater hip flexion occurred in the left leg than the right. In another study, Uetake (1992) stated that foot angle (toe-out position) increased as walking speed decreased. This was needed for lateral balance. The results of this study support this view. At left heel strike, a greater braking force occurred due to a longer left step. As a result, when the right foot contacted the ground the body was moving slower than when the left foot contacted the ground. Uetake (1992) also indicated that lateral differences in strength could cause a person to veer. These results support his contention. The walking trials of each subject were consistent with respect to the direction of the veer, right or left, while the degree of veer did vary from trial to trial.

Kinematic Comparison of Blind Gait and Normal Gait

Comparing blind gait kinematics from this investigation to the normal gait kinematics reported in the literature concluded the following:

1. The right and left step length for this study was 0.669 m and 0.673 m, respectively. Thus, stride length was 1.34 m or 134 cm. Murray et al. (1964) found that the average stride length for sighted individuals was 156 ± 13 cm. Therefore, the mean stride length for the subjects in this study was shorter. Shorter strides provide a greater degree of dynamic equilibrium than longer strides.

2. The right and left foot angles for this study were 24.22° and 17.67°, respectively. Murray et al. (1964) found that the mean right foot angle was 6.7° and the mean left foot angle was 6.8°. Therefore, the right and left foot angles for the subjects in this study were greater. The greater toe-out position would provide more stability by producing a larger base of support in the lateral direction or frontal plane.

3. The stride width for the study was 16.3 ± 2.7 cm. Murray et al. (1964) found that the mean stride width was 8.0 ± 3.5 cm. Therefore, the stride width for the subjects in this study was wider. The wider stride width caused more wasted energy expenditure in the lateral direction when the center of gravity has to be shifted over the support foot during the single leg support phase.

4. The mean ankle angles were 100.74°, 104.44°, 82.22°, and 109.21°, for the heel strike, foot flat, heel off, and toe off positions, respectively. Adrian and Cooper (1989) found the mean ankle angles of 80°, 90°, 85°, and 105° for the heel strike, foot flat, heel off, and toe off positions, respectively. Murray et al. (1964) found the mean ankle angles of 92°, 96°, 85°, and 105° for heel strike, foot flat, heel off and toe off positions, respectively.

5. The mean knee angles were 172.11°, 166.15°, 169.66°, and 128.65° for the heel strike, foot flat, heel off, and toe off positions, respectively. Adrian and Cooper (1989) found mean knee angles of 180°, 155°, 175°, and 145° for heel strike, foot flat, heel off, and toe off positions, respectively. Murray et al. (1964) found mean knee angles of 175°, 160°, 167°, and 110° for heel strike, foot flat, heel off, and toe off positions, respectively.

6. The mean thigh angles were 71.76°, 73.91°, 102.97°, and 90.53° for the heel strike, foot flat, heel off, and toe off positions, respectively. Adrian and Cooper (1989) found mean thigh angles of 60°, 63°, 104°, and 93° for heel strike, foot flat, heel off, and toe off positions, respectively. Murray et al. (1964) found the mean thigh angles of 58°, 63°, 103°, and 70° for heel strike, foot flat, heel off, and toe off positions, respectively.

7. The pelvic rotation means were 93.52°, 92.74°, 93.16°, and 95.34° for the heel strike, foot flat, heel off, and toe off positions, respectively. Murray et al. (1964) found the mean pelvic rotation of 90.0°, 90.5°, 96.3°, and 95.1° for heel strike, foot flat, heel off, and toe off positions, respectively.

Heel strike and foot-flat positions represent the beginning and ending of the braking phase; the first part of the stance phase. During this phase the subject's center of gravity is behind the planted foot and a force is applied to the ground that slows or decelerates the horizontal forward velocity. No noticeable difference is seen in the knee angle for the blind subjects in this study compared to the knee angle of sighted described in the literature. However, the ankle angle is plantar flexed and the thigh angle (hip) is extended more for the subjects in this study compared to the normal gait described in the literature. Plantar flexion and thigh extension during the braking phase would cause a smaller stride length and a smaller step length. This would also assure that the person's walking velocity would be slower than normal. Both step and stride lengths were shorter for the blind subjects studied. A shorter step or stride may be a mechanism that is used by blind or partially sighted to assure equilibrium is maintained in unfamiliar environments. If the foot that is reaching forward makes contact with an unexpected object, stability would be hard to control. This gait pattern may not be evident when the blind or partially sighted are walking in familiar environments.

Foot-flat and heel-off positions represent the beginning and ending of the mid-stance phase; the second part of the stance phase. During this phase the subject's center of gravity rotates up over the support foot preparing the body to push forward into the next stride. To be mechanically efficient, the ankle and knee motion acts together to minimize the vertical displacement of the center of gravity. The ankle continues to dorsal flex as the knee slightly extends to push the body's center of gravity (weight) in front of the stance foot. Since the subjects in this study are more plantar flexed than that reported in the literature, their dorsal flexion range of motion is much greater during this phase than that reported in the literature by Adrian and Cooper (1989) and by Murray (1967). The range of motion of the knee and thigh for the blind subjects is less during this phase than that reported in the literature. However, at the heel-off position the angles of the ankle, knee, and thigh are the same for the subjects in this study and those reported in the literature. These differences in ankle, knee, and thigh range of motion during the mid-stance phase caused the center of gravity of the blind subjects to be displaced farther (7.8 ± 3.1 cm) than what was reported in the literature (6.0 ± 1.3 cm) by Murray (1967).

Heel-off and toe-off positions represent the beginning and ending of the propulsion phase; the third and final part of the stance phase. During this phase the subject's center of gravity is in front of the support foot and the foot is pushing forcefully down and back on the ground. For this study the ankle's range of motion is similar to that reported in the literature; however, the knee does not extend as much as that reported by Adrian and Cooper (1989) but is similar to that reported by Murray et al. (1964). The results for this study indicated that the thigh did not extend as much as that reported by Murray et al. The small range of motion at the knee and thigh found in this study compared to the literature would also contribute to a slower horizontal forward velocity and a shorter step and stride length compared to the data reported in the literature.

CHAPTER V

SUMMARY, FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

Summary

The problem of the study was to describe the gait patterns of congenitally blind adults who veer when attempting to walk in a straight path. Specifically, the investigation compared the walking patterns of blind subjects to the walking patterns of sighted subjects as described in the literature and compared the symmetry between the right and left sides of the body. Data for this study were obtained from 9 congenitally blind individuals. The subjects were oriented with a guided tour to the walking area, for 5 minutes or until they felt comfortable. The subjects wore blindfolds, Walkman, and earmuffs while walking with the aid of their canes for 50 ft or until they were told to stop or tapped on the shoulder. Subjects repeated this procedure 10 times while the researcher recorded the direction of veer, right, left, or no veer. Subjects who consistently veered to the right or the left over 8 of the 10 trials were selected as subjects for the study.

A three-dimensional video analysis was used to evaluate the walking patterns. The cameras were placed at 45° angles to the sagittal plane of the subjects' walking path and perpendicular to one another. The two cameras were synchronized. Each subject performed three walking trials. A stride length starting at right heel strike was analyzed for each of the three trials. The raw digitized coordinates were smoothed (conditioned) with the Butterworth filter set at 6 Hz. An ANOVA was calculated to determine the consistency among the trials. If there was no significant difference among the trials then the mean of the three trials was used in the statistical analysis for testing the research hypotheses. ANOVAs were also calculated among positions (heel strike, foot flat, heel off, and toe off) and between legs. Statistical *t* tests were calculated to check for symmetry between the right and left extremities.

Findings

The significant findings of the study were as follows:

1. No significant differences were found among the three trials for any of the dependent variables except medial/lateral displacement of the center of gravity, $F(2, 16) = 8.96, p = .00$ and right step length $F(2, 16) = 6.52, p = .01$.

2. No significant difference was found between the right and left legs for pelvic rotation, $F(1, 56) = 0.69, p > .05$. The means for the right and left legs were 93.63° and 94.09°, respectively.

3. A significant difference was found among the four positions for pelvic rotation, $F(3, 56) = 4.34, p < .05$. The means for the positions were 94.21°, 92.74°, 93.16°, and 95.34° for the heel strike, foot flat, heel off, and toe off positions, respectively.

4. The first order interaction effect leg by position was significant for pelvic rotation, $F(3, 56) = 6.73, p < .05$.

5. No significant difference was found between the right and left legs for shoulder rotation, $F(1, 56) = 0.081, p > .05$. The means for the right and left legs were 91.36° and 91.30°, respectively.

6. No significant difference was found among the four positions for shoulder rotation, $F(3, 56) = 0.23, p > .05$. The mean for the positions were 91.18°, 91.37°,

91.35°, and 91.42° for the heel strike, foot flat, heel off, and toe off positions, respectively.

7. The first order interaction effect, leg by position, was significant for shoulder rotation, $F(3, 56) = 16.86, p < .05$.

8. No significant difference was found between the right and left legs for trunk inclination, $F(1, 56) = 0.40, p > .05$. The means for the right and left legs were 4.88° and 4.71°, respectively.

9. No significant difference was found among the four positions for trunk inclination, $F(3, 56) = 1.12, p > .05$. The mean for the positions were 5.08°, 4.68°, 4.96°, and 4.46° for on heel strike, foot flat, heel off, and toe off positions, respectively.

10. The first order interaction effect, leg by position, was not significant for trunk inclination, $F(3, 56) = 1.51, p > .05$.

11. A significant difference was found between the right and left legs for the ankle, $F(1, 56) = 8.16, p < .05$. The means for the right and left legs were 97.57° and 100.74°, respectively.

12. A significant difference was found among the four positions for the ankles, $F(3, 56) = 113.10, p < .05$. The mean for the positions were 100.75°, 104.44°, 82.22°, and 109.22° for the heel strike, foot flat, heel off, and toe off positions, respectively.

13. The first order interaction effect, leg by position, was not significant for the ankles, $F(3, 56) = 1.75, p > .05$.

14. No significant difference was found between the right and left legs for knees angle, $F(1, 56) = 1.48, p > .05$. The means for the right and left legs were 158.36° and 159.92°, respectively.

15. A significant difference was found among the four positions for knee angle, $F(3, 56) = 254.70$, $p < .05$. The means positions were 172.11°, 166.15°, 169.66°, and 128.65° for the heel strike, foot flat, heel off, and toe off positions, respectively.

16. The first order interaction effect, leg by position, was not significant for the knee angle, $F(3, 56) = 1.45$, $p > .05$.

17. A significant difference was found between the right and left legs for thigh angle, $F(1, 56) = 4.56$, $p < .05$. The means for the right and left legs were 83.48° and 86.11°, respectively.

18. A significant difference was found among the four positions for thigh angle, $F(3, 56) = 143.43$, $p < .05$. The mean for the positions were 71.76°, 73.91°, 102.97°, and 90.53° for the heel strike, foot flat, heel off, and toe off positions, respectively.

19. The first order interaction effect, leg by position, was not significant for the thigh angle, $F(3, 56) = 0.78$, $p > .05$.

20. No significant difference was found for the foot angles, $t(9) = 1.336$, $p = .218$. The means for the right and left limbs were 24.22° and 17.67°, respectively.

21. No significant difference was found for step length, $t(9) = -1.014$, $p = .340$. The means for the right and left limbs were .67 m and 1.40 m, respectively.

Conclusions

The findings led the investigator to conclude the following:

1. Symmetry was not achieved for medial/lateral displacement, step length, thigh angle, and trunk inclination between the right and left sides of the body. The asymmetry found in step length, lateral displacement, foot angles, and interaction

effects leg by position for shoulder rotation and pelvic rotation apparently caused the veering patterns.

2. Symmetry was achieved for ankle angle, foot displacement, foot position at foot plant, knee angle, pelvic rotation, and shoulder rotation between the right and left sides of the body.

3. The normal gait pattern of the sighted individuals described in the literature was more similar than dissimilar to the subjects in this study. Two differences were found: (1) asymmetry in some variables, and (2) a shorter stride and step length.

Recommendations

The following are recommendations for further research:

1. A larger group would provide greater statistical power and thus more accurately indicate differences between the sighted subjects and blind subjects.

2. Other age groups need to be studied to evaluate the developmental changes, both progressive and regressive, that occur over the lifespan.

3. Females should be studied in a similar project to compare results to those found in males.

4. More data or different variables (e.g., electromyography, velocity for body segments) need to be investigated.

5. Other blind condition (e.g., partially blind, adult blindness, adolescent blindness, childhood blindness) need to be studied to compare to congenitally blind individuals.

Appendix A

Data Sheet

Veering Data Sheet

Subject Code: ____________

Direction of Veer:

R	L	N	Trial 1
R	L	N	Trial 2
R	L	N	Trial 3
R	L	N	Trial 4
R	L	N	Trial 5
R	L	N	Trial 6
R	L	N	Trial 7
R	L	N	Trial 8
R	L	N	Trial 9
R	L	N	Trial 10

Y N Subject for Second Part of Study

Appendix B

Informed Consent Form

Western Michigan University
Department of Health, Physical Education, and Recreation
Principal Investigator: Dr. Mary Dawson
Research Associate: Beth Engler

I have been invited to participate in a research study titled *"A Biomechanical Analysis of the Walking Patterns of Blind Individuals who Consistently Veer"*. This research will described the walking characteristics of congenitally blind people who veer, examine the symmetry between the right and left sides of the body, and compare gait patterns of the congenitally blind to those of sighted people as described in the literature. This project is Beth Engler's master's thesis, a part of her degree requirements.

My consent to participate in this thesis project indicates that I will be asked to attend one, 1-hr session. I will be asked to meet Beth Engler in the Student Recreation Building, Room 1060, Western Michigan University, Kalamazoo. The session will consist of two parts.

First, I will be asked to walk in a barrier free area to determine if I veer, and if so, in what direction. For this part of the study, I will be positioned by the researcher in the center of an indoor tennis court in the Student Recreation Center, Western Michigan University, Kalamazoo. I will wear a blindfold, walkman, and ear muffs while walking with the aid of my cane for 60 ft or until the researcher signals me to stop by grasping my arm directly above the elbow of my cane arm. I will repeat this procedure ten times. For each of the 10 trials, a veering direction will be recorded; right, left, or no veer. If, I veer consistently to the right or the left, I will complete the second part of the data collection session. If, I do not veer in at least 8 of the 10 trials, my participation in the study is completed after the first part of the session.

Second, I will be oriented to a walking area in the Biomechanics Lab, Student Recreation Center, Western Michigan University, Kalamazoo. This orientation period will last about 5 min or until I feel comfortable. During the orientation, I will be physically guided around the area and then given an opportunity to explore the area on my own. After the orientation period, I will be fitted with a blindfold, walkman, ear muffs, and reflective markers (placed on the toe, ankle, knee, hip, pelvis, shoulder, elbow, wrist, trunk, ear, and top of head). For this part of the data collection I will be video taped during 5 walking trials. A trial will consist of: (a) being lead to the starting point on the floor, (b) positioning my feet and shoulders perpendicular to the intended walking path, (c) instructing me to begin walking in a straight line, and (d) signaling me to stop walking. Each trial will consist of 10-15 steps in a barrier free area for the purpose of video taping. I will use my cane to assist me during the five trials. Guide dogs or human assistance will not be permitted.

I am aware that the current testing may be of no benefit to me. Knowledge of the mechanics of people who are congenitally blind and who veer may help mobility instructors in correcting the problem.

As in all research, there may be unforeseen risks to the participant. The risks to the research participant in this study include those risks taken in normal daily situations. The risks include stumbling and possibly falling. A person trained in first aid will be present during the filming. If an emergency arises, appropriate immediate care will be provided and I will be referred to the Sindecuse Health Center. No compensation or treatment will be made available to me except as otherwise specified in this consent form.

All information concerning my participation is confidential. This means that my name will not appear in any document related to this study. The forms will all be coded. Beth Engler will keep a separate master list with the names of all participants and their code numbers. Once the data are collected and analyzed, the master list will be destroyed. The consent and data forms, a disk copy of the electronic generated data, and the video tapes will be retained for a minimum of 3 years in a locked file in the principal investigator's laboratory. A second disk copy of the electronic data will be stored by Beth Engler for a minimum of 3 years.

I may refuse to participate or quit at any time during the study without any effect on my grades or relationship with Western Michigan University. If I have any questions or concerns about this study, I may contact either Dr. Mary Dawson at (616) 387-2546 or Beth Engler at (616) 387-2710. I may also contact the Chair of Human Subjects Review Board at (616) 387-8293 or the Vice President for Research at (616) 387-8928 with any concern that I have. My signature below indicates that I am aware of the purpose and requirements of the study and that I agree to participate.

This consent document has been approved for use for 1 year by the Human Subjects Institutional Review Board (HSIRB) as indicated by the stamped date and signature of the board chair in the upper right hand corner of both pages of this consent form. Subjects should not sign this if the corners do not show a stamped date and signature.

____________________________________ ____________________

Signature of Participate Date

____________________________________ ____________________

Signature of Investigator Obtaining Consent Date

Appendix C

Human Subjects Institutional Review Board Approval

Human Subjects Institutional Review Board

Kalamazoo, Michigan 49008-3899

WESTERN MICHIGAN UNIVERSITY

Date: 10 February 1999

To: Mary Dawson, Principal Investigator
Beth Engler, Student Investigator for thesis

From: Sylvia Culp, Chair *Sylvia Culp*

Re: HSIRB Project Number 99-01-08

This letter will serve as confirmation that your research project entitled "A Biomechanical Analysis of the Walking Patterns of Blind Individuals Who Consistently Veer" has been **approved** under the **expedited** category of review by the Human Subjects Institutional Review Board. The conditions and duration of this approval are specified in the Policies of Western Michigan University. You may now begin to implement the research as described in the application.

Please note that you may **only** conduct this research exactly in the form it was approved. You must seek specific board approval for any changes in this project. You must also seek reapproval if the project extends beyond the termination date noted below. In addition if there are any unanticipated adverse reactions or unanticipated events associated with the conduct of this research, you should immediately suspend the project and contact the Chair of the HSIRB for consultation.

The Board wishes you success in the pursuit of your research goals.

Approval Termination: 10 February 2000

Appendix D

ANOVA Summary for Trial Consistency

Appendix D

ANOVA Summary for Trial Consistency

Variable	Source	*SS*	*df*	*MS*	*F*	*p*
Left Ankle						
R-HS	Trials	55.50	2	27.75	1.77	.20
	Residual	250.61	16	15.66		
R-FF	Trials	16.51	2	8.25	.40	.68
	Residual	329.74	16	20.61		
R-HO	Trials	20.20	2	10.10	.26	.77
	Residual	618.02	16	38.63		
R-TO	Trials	63.31	2	31.66	3.07	.08
	Residual	165.15	16	10.32		
L-HS	Trials	.592	2	.27	.01	.99
	Residual	499.83	16	31.24		
L-FF	Trials	5.88	2	2.94	.14	.87
	Residual	346.187	16	21.64		
L-HO	Trials	38.7	2	19.35	.80	.47
	Residual	387.08	16	24.19		
L-TO	Trials	9.931	2	4.97	.21	.82
	Residual	392.48	16	24.53		
Left Knee						
R-HS	Trials	43.40	2	21.70	1.38	.28
	Residual	251.59	16	15.72		
R-FF	Trials	62.26	2	31.13	.78	.48
	Residual	642.38	16	40.15		
R-HO	Trials	89.83	2	44.91	1.38	.28
	Residual	522.21	16	32.64		
R-TO	Trials	2.28	2	1.14	.03	.97
	Residual	596.90	16	37.31		
L-HS	Trials	13.57	2	6.78	.23	.80
	Residual	475.59	16	29.73		
L-FF	Trials	12.09	2	6.05	.30	.74
	Residual	319.09	16	19.94		
L-HO	Trials	37.44	2	18.72	1.20	.33
	Residual	250.51	16	15.66		
L-TO	Trials	103.00	2	51.50	.88	.44
	Residual	941.14	16	58.82		
Left Thigh						
R-HS	Trials	24.48	2	12.24	.19	.83
	Residual	1033.29	16	64.58		
R-FF	Trials	21.75	2	10.82	.18	.84
	Residual	965.11	16	60.32		

Appendix D—Continued

Variable	Source	*SS*	*df*	*MS*	*F*	*p*
R-HO	Trials	166.90	2	83.45	1.09	.36
	Residual	1225.84	16	76.62		
R-TO	Trials	128.16	2	64.08	1.00	.39
	Residual	1022.20	16	63.89		
L-HS	Trials	118.93	2	59.47	.75	.49
	Residual	1264.24	16	79.02		
L-FF	Trials	73.43	2	36.71	.43	.66
	Residual	1377.59	16	86.10		
L-HO	Trials	60.12	2	30.06	.51	.61
	Residual	944.41	16	59.03		
L-TO	Trials	19.67	2	9.84	.28	.76
	Residual	569.86	16	35.62		
Right Ankle						
R-HS	Trials	239.13	2	119.56	2.11	.15
	Residual	905.40	16	56.59		
R-FF	Trials	47.92	2	23.96	1.43	.27
	Residual	268.57	16	16.79		
R-HO	Trials	126.39	2	63.20	2.14	.15
	Residual	473.60	16	29.60		
R-TO	Trials	140.08	2	70.04	1.08	.36
	Residual	1037.59	16	64.85		
L-HS	Trials	136.77	2	68.39	1.55	.24
	Residual	706.14	16	44.13		
L-FF	Trials	138.67	2	69.34	1.57	.24
	Residual	705.02	16	44.06		
L-HO	Trials	42.77	2	21.38	.45	.65
	Residual	765.58	16	47.85		
L-TO	Trials	101.59	2	50.80	2.84	.09
	Residual	286.59	16	17.91		
Right Knee						
R-HS	Trials	151.27	2	75.63	.54	.59
	Residual	2229.94	16	139.37		
R-FF	Trials	14.90	2	7.45	.69	.52
	Residual	172.13	16	10.76		
R-HO	Trials	23.04	2	11.52	.71	.50
	Residual	258.04	16	16.13		
R-TO	Trials	96.00	2	48.00	.50	.61
	Residual	1526.03	16	95.38		
L-HS	Trials	28.44	2	14.22	.78	.48
	Residual	292.60	16	18.29		
L-FF	Trials	57.93	2	28.96	.57	.58
	Residual	812.09	16	50.76		

Appendix D—Continued

Variable	Source	*SS*	*df*	*MS*	*F*	*p*
L-HO	Trials	5.09	2	2.54	.17	.85
	Residual	244.83	16	15.30		
L-TO	Trials	87.59	2	43.80	.86	.44
	Residual	816.89	16	51.06		
Right Thigh						
R-HS	Trials	207.73	2	103.86	1.25	.31
	Residual	1326.95	16	82.93		
R-FF	Trials	132.38	2	66.19	1.09	.36
	Residual	972.11	16	60.76		
R-HO	Trials	187.79	2	93.90	1.28	.31
	Residual	1172.06	16	73.25		
R-TO	Trials	45.20	2	22.60	.60	.56
	Residual	606.94	16	37.93		
L-HS	Trials	214.27	2	107.14	1.36	.28
	Residual	1257.40	16	78.59		
L-FF	Trials	86.96	2	43.48	.77	.48
	Residual	902.71	16	56.42		
L-HO	Trials	170.46	2	85.23	1.12	.35
	Residual	1221.05	16	76.32		
L-TO	Trials	37.35	2	18.68	1.05	.37
	Residual	285.00	16	17.81		
Pelvic Rotation						
R-HS	Trials	11.77	2	5.89	.79	.47
	Residual	119.72	16	7.48		
R-FF	Trials	1.94	2	.97	.16	.86
	Residual	97.66	16	6.10		
R-HO	Trials	10.22	2	5.11	.35	.71
	Residual	232.21	16	14.51		
R-TO	Trials	31.50	2	15.75	1.56	.24
	Residual	161.33	16	10.08		
L-HS	Trials	11.29	2	5.65	.64	.54
	Residual	142.25	16	8.89		
L-FF	Trials	12.00	2	6.00	.46	.64
	Residual	209.56	16	13.10		
L-HO	Trials	6.75	2	3.38	.39	.69
	Residual	139.85	16	8.74		
L-TO	Trials	.49	2	.24	.015	.99
	Residual	267.61	16	16.73		
Shoulder Rotation						
R-HS	Trials	.96	2	.48	.31	.74
	Residual	24.86	16	1.55		
R-FF	Trials	5.54	2	2.77	3.34	.06
	Residual	13.27	16	.83		

Appendix D—Continued

Variable	Source	*SS*	*df*	*MS*	*F*	*p*
R-HO	Trials	4.91	2	2.46	1.69	.22
	Residual	23.32	16	1.46		
R-TO	Trials	.48	2	.24	.13	.87
	Residual	28.97	16	1.81		
L-HS	Trials	3.80	2	1.90	1.26	.31
	Residual	24.12	16	1.51		
L-FF	Trials	.66	2	.33	.23	.80
	Residual	22.82	16	1.43		
L-HO	Trials	2.55	2	1.27	.93	.42
	Residual	22.03	16	1.38		
L-TO	Trials	6.74	2	3.37	3.50	.06
	Residual	15.42	16	.96		
Trunk Inclination						
R-HS	Trials	4.98	2	2.49	1.16	.34
	Residual	34.36	16	2.15		
R-FF	Trials	3.11	2	1.56	.63	.54
	Residual	39.25	16	2.45		
R-HO	Trials	5.90	2	2.95	1.16	.34
	Residual	40.85	16	2.55		
R-TO	Trials	6.44	2	3.22	2.92	.08
	Residual	17.62	16	1.10		
L-HS	Trials	13.31	2	6.65	2.26	.14
	Residual	47.14	16	2.95		
L-FF	Trials	7.48	2	3.74	1.93	.18
	Residual	31.06	16	1.94		
L-HO	Trials	2.92	2	1.46	.77	.48
	Residual	30.53	16	1.91		
L-TO	Trials	3.15	2	1.57	1.13	.35
	Residual	22.31	16	1.40		
Left Foot Angle						
	Trials	156.93	2	78.46	.72	.50
	Residual	1755.42	16	109.71		
Right Foot Angle						
	Trials	527.74	2	263.87	2.84	.09
	Residual	1488.32	16	93.02		
Left Step length						
	Trials	.0012	2	.00058	1.41	.87
	Residual	.066	16	.0041		
Right Step length						
	Trials	.093	2	.046	6.52	.01
	Residual	.11	16	.0071		
Horizontal Center of Gravity						
	Trials	.0020	2	.00099	8.96	.001
	Residual	.0018	16	.00011		

Appendix D—Continued

Variable	Source	*SS*	*df*	*MS*	*F*	*p*
Vertical Center of Gravity						
	Trials	.0039	2	.0020	.98	.40
	Residual	.032	16	.0020		
Right/Left Foot Displacement						
	Trials	.00074	2	.00037	.085	.92
	Residual	.0689	16	.0043		

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