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A biomechanical evaluation of visually impaired persons' gait and long-cane mechanics

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Abstract —

This study was designed to compare selected kinematic components of gait and long cane mechanics between groups of visually impaired travelers. Twenty subjects were placed in Traditional or Modified technique groups according to their long cane traveling technique. Subjects were measured during the following conditions; 1) normal walking (NW), 2) walking while anticipating a simulated drop-off (AD), 3) walking while responding to an audible task (ST) and, 4) walking while anticipating a simulated drop-off and responding to an audible task (STAD). Data were analyzed using a repeated measures analysis of variance (ANOVA) and

Pearson's r-correlation coefficient. Analyses revealed no differences between groups of travelers. However, significant differences were noted between trials for components of gait velocity, stride length, and hip flexion velocity. These findings may indicate a potentially dangerous alteration in the normal gait cycle of visually impaired travelers when faced with additional attention-demanding tasks while walking.

Key words: biomechanics, blindness, kinematics, orientation and mobility, travel.

INTRODUCTION

Human gait analysis has, for many years, been at the center of numerous biomechanical research studies. Gait velocity (GV), stride length (SL), stride rate (SR), and other related joint angle parameters are variables most often examined when studying walking patterns. However, the bulk of gait research has been performed on the sighted population. These studies have included analyses of normal gait of varying age groups, abnormal gait due to injury or disease, and gait patterns with respect to gender. Few studies have investigated the gait cycle in the visually impaired population, which numbers over 2 million in the United States. Biomechanical research that has been conducted within this population has focused on GV, SL, SR, and long-cane techniques with regard to orientation and mobility (O&M) training (1,2).

Limited measures of postural stability and balance have also been recorded for visually impaired subjects. Elliott, Patla, Flanagan et al. (3) found significant differences in balance and postural parameters between sighted and visually impaired groups. Adding an attention-demanding task to the testing protocol further degraded the scores for each group. These data indicate the increased risk involved with balance maintenance while attending to an external stimulus. This risk factor is further compounded for the visually impaired traveler who must be cognizant of obstacles in the path of travel while maintaining awareness of audible cues.

A better understanding of the physical challenges faced by individuals with visual impairment is needed in order to improve the mobility and independence of this group of people. Research indicates that mobility is strongly correlated with self-perceived physical performance (4). Analyzing and evaluating the gait of visually impaired subjects may lead to refinements in O&M training, thereby providing a significant increase in the performance of activities of daily living (ADLs). Possible improvements could be made in the amount of path coverage and preview time a mobility traveler has while walking. A deficiency in either component could decrease the ability to detect a path obstacle, which could lead to a fall and injury. Quantitative analyses of joint angle range of motion (ROM) and angular velocity combined with assessment of GV, SL, SR, and long-cane techniques could prove beneficial in determining the dynamic effects that vision loss manifests on gait.

The independent mobility of visually impaired persons is greatly expanded through the systematic approach of O&M training offered at Blind Rehabilitation Centers (BRCs). Patients progress through a sequence of mobility tasks that include walking with a sighted guide and negotiating predetermined paths using only the long-cane. Typical O&M training requires between 6 and 12 weeks before an individual is able to travel alone safely. One study (1) revealed gait velocities increased when path preview was extended from 1 to 5 m through the use of a Sonic Pathfinder device. These findings were corroborated by another that found patients had greater gait velocities while walking with a sighted guide, indicating the insecurity felt by visually impaired pedestrians when traveling alone (5).

Increasing the preview distance of travel is the basis of long-cane mobility training. Traditional long-cane techniques recommend: 1) the hand holding the cane be centered in front of the body, 2) the cane tip should swing from side to side in rhythm with the traveler's footfalls in a horizontal arc approximately shoulder width, and 3) the cane tip should touch the ground at each extreme of the shallow vertical arc described by the cane (6). Modified long-cane techniques have been defined as any that deviate from this recommended method. A recent study (2) compared long-cane kinematics between a group of visually impaired subjects and a group of sighted mobility instructors whose vision was intentionally obstructed. The findings indicated that the traditional long-cane techniques exhibited by both groups did not provide sufficient path coverage and, therefore, were not adequate for the detection of obstacles along the route of travel.

Loss of vision and its impact on ADLs are well documented. One study demonstrated the effects of systematic removal of visual feedback on a group of sighted subjects (7). The testing protocol required subjects to track a computer-generated target on a video screen using a joystick with varying times of visual preview. A strong linear correlation was noted between preview time and tracking accuracy, indicating that visual feedback is an important factor in maintaining spatial acuity. Additional visual factors and their relationship to O&M performance were verified in a study in which 19 low vision patients were recruited to examine the relationships between visual field, spatial contrast, visual acuity, and O&M. Subjects were required to navigate two predetermined courses through a series of fixed obstacles of varying shape, size, and contrast at varying light levels. Points were tallied based on the number of contacts made with each obstacle during each trial. Visual field and contrast sensitivities were found to have the greatest impact on successful course navigation (8). The results from this study suggest that type of vision loss is an important factor in O&M performance.

Perhaps the most significant element determining the ability of visually impaired persons to perform ADLs is their self-perceived physical function. Physical function was assessed in 417 elderly subjects via the standardized Sickness Impact Profile (SIP). Score analysis was determined through scores tallied from self-perceived function-based performance of gait speed, grip strength, chair-stand time, and balance (4). A significant correlation was found between GV and self-perceived physical performance ($p<0.01$). Although the results revealed only moderate correlations between actual GV and perceived physical performance, it can be hypothesized that self-perception is an important factor in how an individual confronts the challenges of performing ADLs. This self-perception may be even more meaningful to persons with visual impairment.

Self-perceived physical function is a positive subjective indicator of a person's ability and willingness to travel independently. Quantitative kinematic assessment of a visually impaired individual's gait cycle may provide valuable objective information regarding the complex interaction between walking and long-cane mobility techniques. The purpose of this study was to compare specific components of gait and long-cane technique between two groups of visually impaired subjects with prior mobility training. Subjects were tasked with normal walking while using a long-cane (NW), walking with a long-cane while responding to an audible attention-demanding task (ST), reacting to a simulated drop-off while walking with a long-cane (AD), and walking while responding to both an audible attention-demanding task and a simulated drop-off (STAD), in order to determine the effects of visual impairment and additional tasking on motor locomotion. Key components of this study include:

1. The development and construction of a prototype retractable cane to simulate a drop-off and/or level change.
2. The examination of what impact additional tasking has on visually impaired gait.
3. The determination of how the introduction of an additional task affects the visually impaired individual's ability to detect a drop-off.

METHODOLOGY

Subjects

Twenty persons with visual impairment (mean age 50.3±14.9 years) volunteered for this study: 18 men and 2 women. Subject age and height ranged from 28-73 years and 1.5-1.95 m respectively. Low-vision patients from the VA Medical Center, the North Georgia Center for Blind Rehabilitation, and the Center for Visually Impaired, Atlanta, GA, were recruited and screened prior to testing. Requirements for participation included: 1) a diagnosis of visual impairment; 2) completion of an O&M course within the past 5 years; and 3) no other physical impairment. Subjects read or had read to them a VA Human Investigations Committee consent form, outlining the testing protocol as well as the potential for injury and other health and safety concerns that could occur from participation. Subjects signed the consent form as approved by Emory University Human Investigations Committee and were prepared for testing; all received a $25 stipend for taking part in the study.

Vision for the group ranged from a corrected value of 20/200 to total blindness. Causes of vision loss included glaucoma, cataracts, macular degeneration, shrapnel and gunshot wounds, and birth defect. Subjects were categorized as having Traditional (TRAD) or Modified (MOD) mobility, based on their long-cane technique. Grouping designations were determined by a three-person panel of O&M instructors, based upon their review of videotaped walking trials of the subjects as they walked outside their homes. Inter-rater reliability was measured by comparing the number of like-subject designations (TRAD or MOD) among the O&M experts. Reliability was calculated at r=0.80 for the 20 subjects. Subjects were required to wear comfortable clothing and walking shoes (i.e., tennis shoes, loafers with no heel) during the testing protocol and performed all trials at a self-selected pace.

Instrumentation

A data capture system (Motion Analysis Corporation, Santa Rosa, CA) was used to record the subjects as they performed the trials. Three charged coupling device video cameras, with a recording rate of 60 pictures per second, were connected to a video processing unit and computer and arranged in a hallway at the Rehab R&D Center at the Atlanta VA Medical Center to create a calibrated recording area of 2.44×3.65 m. A schematic of the setup is shown in **Figure 1.**

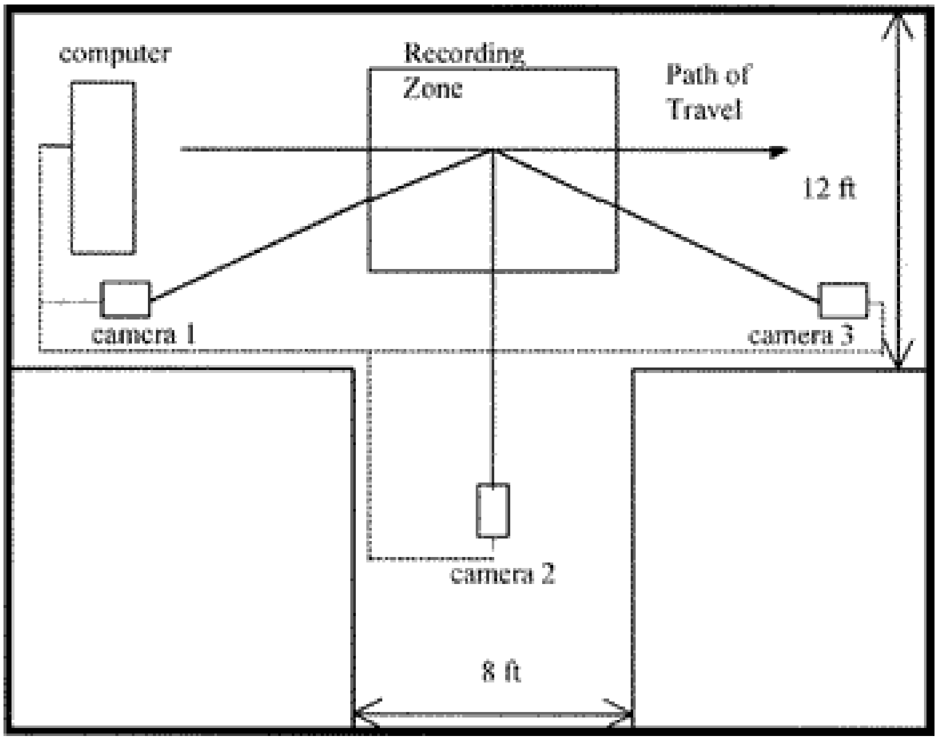

Figure 1. Schematic diagram of three-camera motion capture array used during recording.

Ten reflective markers were placed on the subjects at the following locations: 1) top of head, 2) bill of cap, 3) shoulder, 4) elbow, 5) wrist, 6) hip, 7) knee, 8) ankle, 9) cane-grip, and 10) cane-tip. All joint markers were centered on the axes of rotation, located by palpating the known bony landmarks at each major joint. Markers were placed only on the dominant side (all were right-hand dominant), due to the inability of the data capture system to track a full-body set of markers using three cameras. Markers were illuminated by an array of infrared lights. This recording requirement necessitated a reduction in the ambient white light of the calibrated area. The resulting recording environment was very dark, which precluded subjects from utilizing any residual vision for navigation. Video data were transmitted directly to the system's video processing unit, where three-dimensional (3-D) path data were calculated from the direct linear transformation of the 2-D video data.

Cane Design

A prototype retractable cane (PRC) was constructed from two pieces of hollow graphite tubing totaling 142 cm in length. Normal long-cane length is determined by the approximate height from the ground to the sternum. Since 98 percent of veterans with visual impairments are men whose average height ranges from 173-180 cm, the research team decided to design and build a PRC that would best suit this population sample. The cane-tip section was designed so that the overall length could be reduced by approximately 15 cm using an elastic cord and triggering mechanism, in order to simulate the sensation of the cane tip dropping over the edge of a curb or level change. Shortening or dropping both reduce the angle between the forearm and the user's hand, and this angular decrease, combined with other tactile feedback, alerts the traveler to the potentially hazardous drop-off.

The PRC could be reset to full length after each retraction by pulling the overlapping sections apart. A system of small servomotors, cable, radio-frequency receiver, and latch mechanism was attached to the cane tubing to achieve the desired operation. Retraction was initiated by activating a hand-held radio-frequency transmitter sometime during the gait cycle. Retraction noise was negligible since subjects were required to wear a lightweight headset during testing. The prototype was approximately 40 percent heavier than a standard long cane of equal length; however, its center of mass location was comparable to that of a standard cane. The PRC is shown in **Figure 2** in the retracted position.

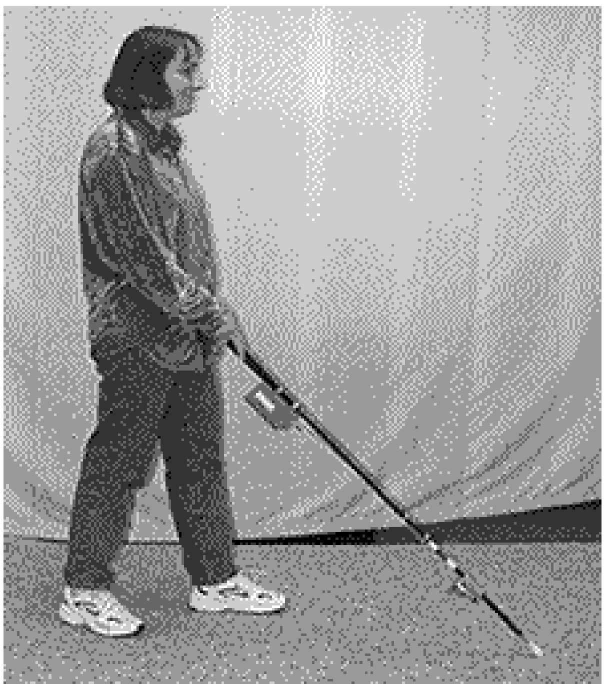

Figure 2. Prototype cane (PRC) in retracted configuration.

Figure 3 shows the cane in the extended position. Note that the subject wears headphones and holds an audible tasking device. White markers located in the middle of the cane body indicate the total retraction amount of the prototype.

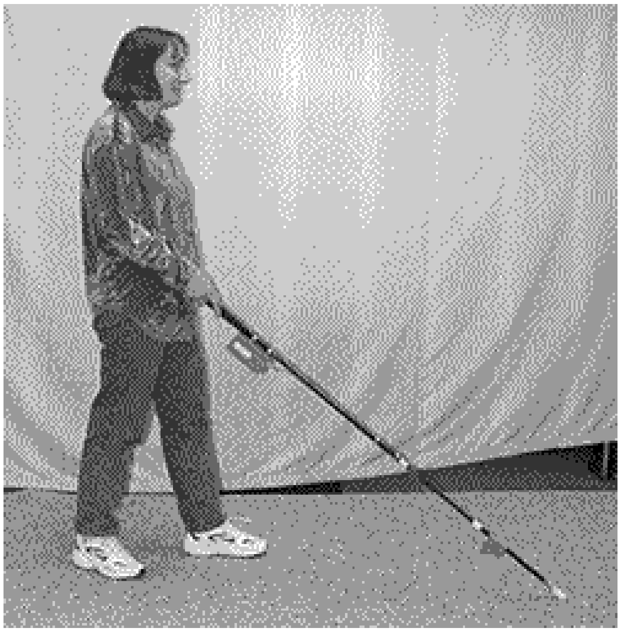

Figure 3. PRC in extended configuration.

Procedure

Subjects walked a total of seven times along a 7.6-m path under four conditions in the following order. Four trials were performed under normal conditions, two with each subject using his/her own cane, and two using the PRC. These four trials established the baseline data (NW); subjects were not outfitted with the calculator, headphones, or battery packs during them. Three additional trials required walking with a retraction of the PRC simulating a drop-off scenario (AD), walking while responding to an audible attention-demanding task (ST), and walking with both the attention-demanding task and the simulated drop-off (STAD). The testing order was not randomized in order to maintain a degree of safety in the subject group, which has the increased potential of instability and falling, and to fulfill the requirement of the Human Investigations Committee to explain in detail the protocol. It was also necessary to train each subject on the use of the retractable cane and programmable calculator prior to testing. The attention-demanding task consisted of the subjects holding a programmable calculator connected to their headphones that, upon activation, emitted a series of audible tones to which the subjects were required to respond as quickly as possible by pressing a button on the calculator.

Statistical Analysis

Twelve dependent variables were examined, including wrist, hip, and knee ROM and angular velocity, GV, SR, and SL. Data were analyzed using a two-way repeated measures analysis of variance to determine whether a significant relationship existed between groups rated as having TRAD or MOD long-cane techniques for these variables. The TRAD and MOD groups consisted of data from eight and nine subjects, respectively. Data for 3 of the 18 male subjects were omitted due to missing marker coordinates. Female subjects were placed one to each group. Statistically significant dependent variables were then compared using a paired-samples t-test to determine which of the trials within-groups were different as indicated by the repeated measures ANOVA.

Independent variables consisted of the TRAD or MOD group designation, with four levels determined by each of the four trial configurations (NW, AD, ST, STAD). Results from the dependent variables measured and analyzed during this study represent maximum and minimum values. All data were analyzed at a significance level of (α=0.05. A Pearson's correlation coefficient was used to determine relationships between and within-groups for the variables found to be significantly different.

RESULTS

Figure 4 illustrates a representative linear displacement position curve of the ankle for a single subject during NW. Distance between heel strikes was calculated from the associated data table to determine SLs for subjects during all trials.

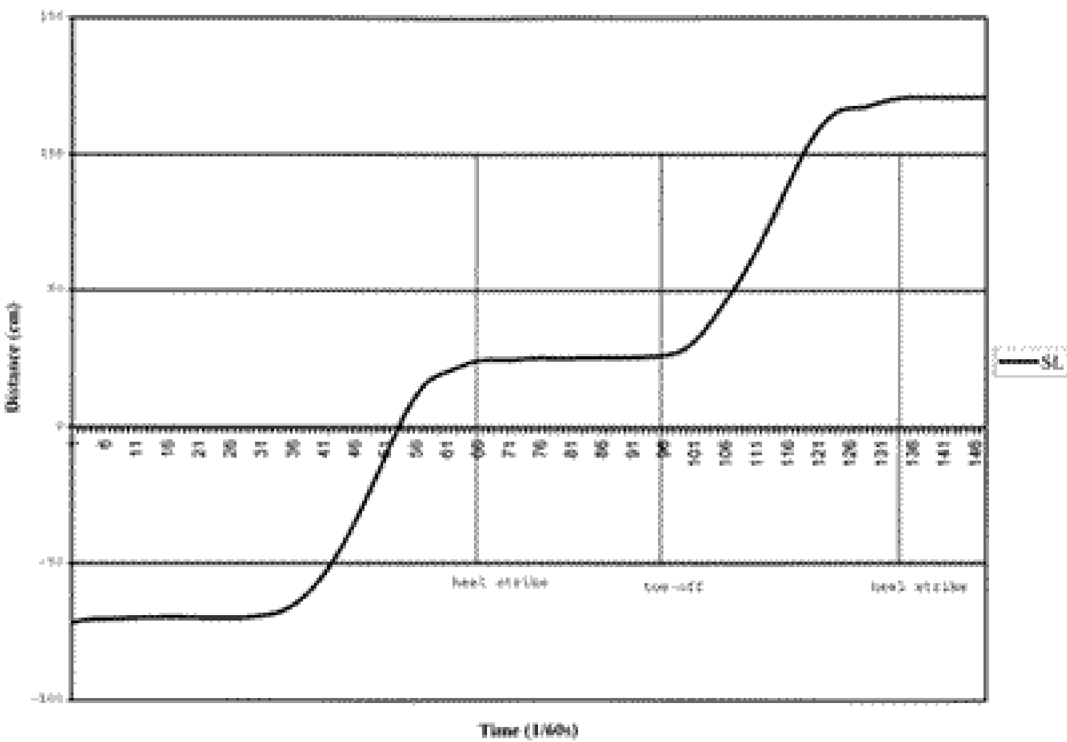

Figure 4. Horizontal linear displacement position curve of the ankle for a representative normal gait cycle.

Figure 5 is a representative graphical illustration of the angular position curve of the knee during NW. The vertical drop lines indicate heel strike and toe-off gait cycle events.

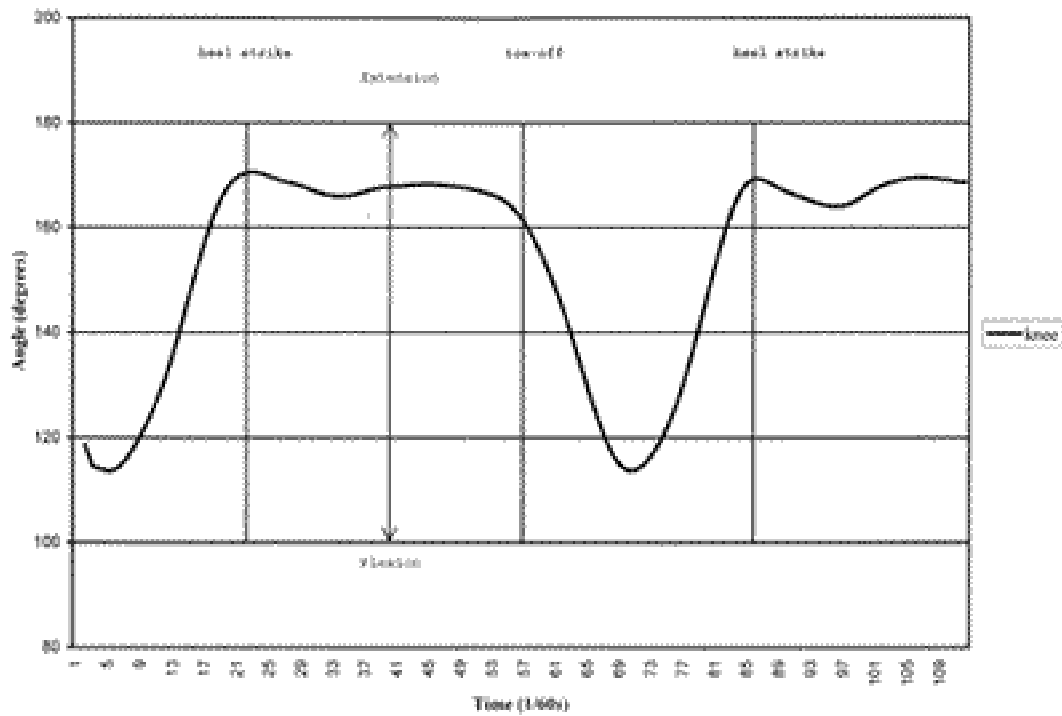

Figure 5. Angular position curve of the knee for a representative gait cycle.

Hip angular position of a normal gait cycle is illustrated in **Figure 6.** Hip extension, flexion, and the gait cycle events of toe-off and heel strike are indicated by vertical drop-lines. Angular ROM was analyzed using peak extension and flexion values.

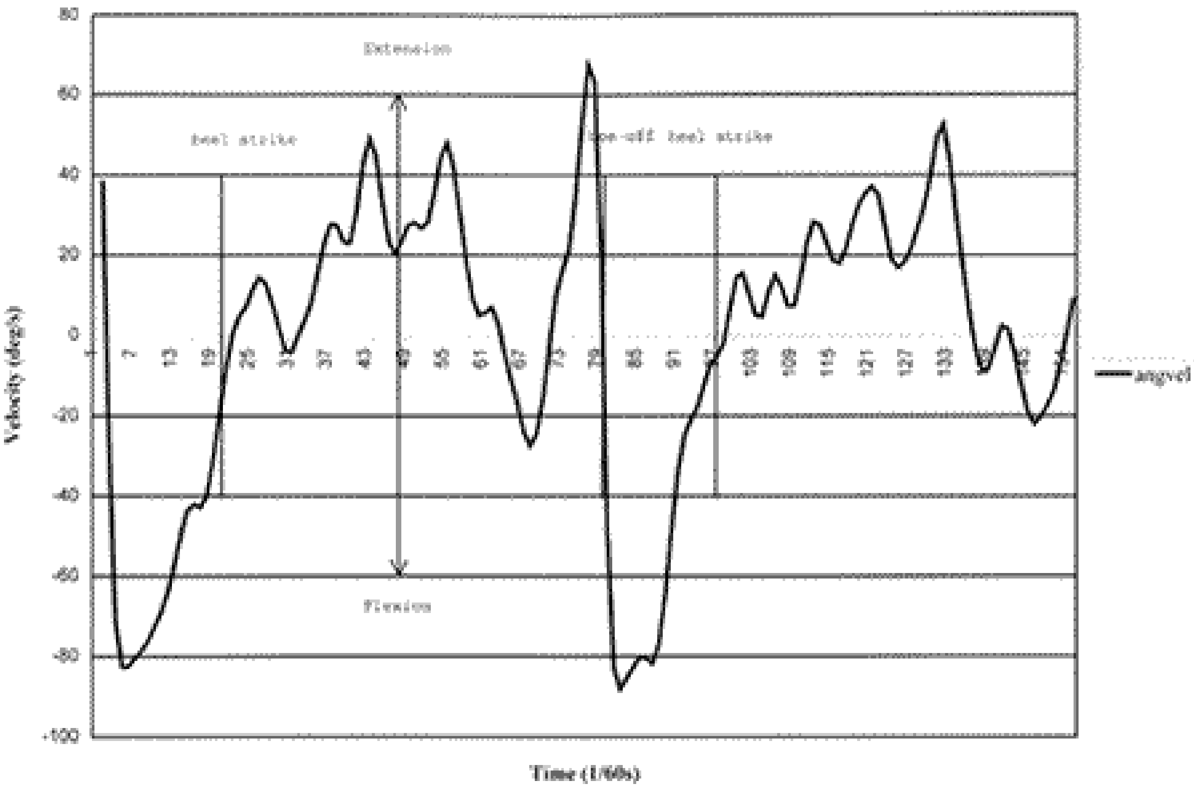

Figure 6. Representative hip angular position curve for a normal gait cycle.

Table 1 presents descriptive data for GV, SL, and SR. The repeated measures ANOVA indicate significant differences within-groups, p;lt0.01 (degrees of freedom (df)=45), for GV and SL but not for SR. However, values for all three variables are included due to the direct proportion of SR to GV, represented by the equation *GV=SL×SR.*

Table 1.

Gait velocities, stride lengths, and stride rates for TRAD and MOD technique and overall group totals.

	GV=SL×SR			
	NW	**AD**	**ST**	**STAD**
TRAD (N = 8)				
GV	127.69 (25.90)	84.62 (47.68)	123.97 (18.22)	71.02 (19.05)
SL	101.38 (14.13)	68.42 (35.84)	98.73 (14.97)	65.58 (19.18)

SR	1.25	1.23	1.26	1.13
	(0.09)	(0.21)	(0.11)	(0.36)
MOD (N = 9)				
GV	117.87	88.58	107.72	86.79
	(25.33)	(39.53)	(24.05)	(45.97)
SL	90.12	67.82	87.71	68.17
	(16.87)	(25.04)	(17.74)	(30.81)
SR	1.31	1.25	1.26	1.23
	(0.14)	(0.21)	(0.14)	(0.26)
TOTAL (N = 17)				
GV	122.49	86.72	115.37	79.37
	(25.29)	(42.19)	(22.46)	(35.80)
SL	95.41	68.10	91.84	66.95
	(16.22)	(29.59)	(17.33)	(25.25)
SR	1.28	1.24	1.26	1.18
	(0.12)	(0.20)	(0.12)	(0.31)

GV=gait velocity in cm/s; SL=stride length in cm; SR=stride rate in steps/s; all as means (SD); NW=normal walking; AD=cane retraction; ST=walking with response to audible tone; STAD=cane retraction combined with audible tone.

Table 2 presents descriptive data for components of the hip including ROM, maximum flexion velocities (FXV), and maximum extension velocities (EXV) for each of the four trial scenarios (NW, AD, ST, STAD). All values of hip flexion velocity were found to be significant within-group ($p<0.01$).

Table 2.

Hip range of motion, flexion velocity, and extension velocity.

	NW	**AD**	**ST**	**STAD**
TRAD (N = 8)				
ROM	22.14	21.56	22.85	22.51
	(4.95)	(7.28)	(5.13)	(4.51)
FXV	-137.34	-129.60	-130.77	-143.63
	(29.00)	(43.94)	(31.88)	(28.65)
EXV	102.28	111.14	128.95	101.26
	(27.54)	(48.77)	(45.40)	(934.63)
MOD (N = 9)				

ROM	22.70 (4.09)	21.16 (5.12)	21.12 (3.43)	23.30 (6.86)
FXV	-118.56 (28.21)	-108.67 (28.34)	-112.67 (16.68)	-127.12 (41.48)
EXV	94.44 (20.98)	82.48 (24.25)	97.49 (30.92)	98.73 (40.52)
TOTAL (N = 17)				
ROM	22.44 (4.38)	21.35 (6.03)	22.47 (4.19)	22.93 (5.71)
FXV	-127.40 (29.31)	-118.52 (36.91)	-121.19 (25.89)	-134.89 (35.94)

ROM=range of motion in degrees; FXV=peak flexion velocity in degrees/s; EXV=peak extension velocity in degrees/s; all as means (SD); NW=normal walking; AD=cane retraction; ST=walking with response to audible tone; STAD=cane retraction combined with audible tone.

Table 3 represents between-subjects and within-subjects repeated measures ANOVA results of GV. A significance difference of $p<0.01$ (df=45) was found for the within-subject by trial effect.

Table 3.
ANOVA results for gait velocity comparison by group and trial.

Gait Velocity	**Between-Subjects Effects**		
	DF	**F**	**Sig**
Within+Residual	15		
Group	1	0.02	0.89
	Within-Subject Effects		
Within+Residual	45		
Factor1	3	10.52	**0.00**
Group by Factor	3	1.16	0.33

DF=degrees of freedom; F=f value; Sig=significance of F; bold face=significant difference at $p<0.01$.

Table 4 represents between-subjects and within-subjects ANOVA results for SL comparison. A significant difference of $p<0.01$ (df=45) was calculated for the within-subject effect.

Table 4.
ANOVA results for stride length comparison by group and trial.

Stride Length	Between-Subjects Effects		
	DF	F	Sig
Within+Residual	15		
Group	1	0.49	0.50
		Within-Subject Effects	
Within+Residual	45		
Factor1	3	11.48	**0.00**
Group by Factor	3	0.73	0.54

DF=degrees of freedom; F=f value; Sig=significance of F; bold face=significant difference at $p<0.01$.

The ANOVA results for SR comparison are presented in **Table 5.** No significant differences for the between-subjects or within-subject effects were found ($p<0.05$, df=15, 45).

Table 5.
ANOVA results for stride rate comparison by group and trial.

Stride Rate	Between-Subjects Effects		
	DF	F	Sig
Within+Residual	15		
Group	1	0.43	0.52
		Within-Subject Effects	
Within+Residual	45		
Factor1	3	1.03	0.39
Group by Factor	3	0.24	0.87

DF=degrees of freedom; F=f value; Sig=significance of F.

Paired samples t-tests were used to examine significant differences between gait trials (NW, AD, ST, STAD). Results indicate significant differences between normal walking and attention-demanding tasked walking for GV. **Table 6** represents the t-test result for GV. Six trial comparisons were examined for each of the three dependent variables found to be significantly different from the ANOVA results.

Table 6.

T-test comparison results for gait velocity.

Gait Velocity t-Test	DF	Sig
NW-AD	16	**0.00**
NW-ST	16	**0.03**
NW-STAD	16	**0.00**
AD-ST	16	**0.01**
AD-STAD	16	0.57
ST-STAD	16	**0.00**

DF=degrees of freedom; Sig=significance of F; bold face=significant difference at p<0.01; NW-AD=normal walking with cane retraction; NW-ST=normal walking with response to audible tone; NW-STAD normal walking compared with with cane retraction and audible tone; AD-STAD=walking with cane retraction compared with cane retraction and audible tone; ST-STAD=walking with audible tone compared with cane retraction and audible tone.

T-test results for SL comparisons are presented in **Table 7.** Significant differences were noted for trial comparisons of NW-ST (p<0.01, df=16) and AD-ST (p<0.05, df=16).

Table 7.

T-test comparison results for stride length.

Stride Length t-Test	DF	Sig
NW-AD	16	0.06
NW-ST	16	**0.00**
NW-STAD	16	0.45
AD-ST	16	**0.05**

AD-STAD	16	0.68
ST-ADST	16	0.15

DF=degrees of freedom; Sig=significance of F; bold face=significant difference at p<0.01; NW-AD=normal walking with cane retraction; NW-ST=normal walking with response to audible tone; NW-STAD normal walking compared with with cane retraction and audible tone; AD-STAD=walking with cane retraction compared with cane retraction and audible tone; ST-STAD=walking with audible tone compared with cane retraction and audible tone.

ANOVA results for hip flexion velocity are presented in **Table 8.** No significant differences were found for the between-subjects analysis. However, a significant difference of p=0.04 (df=45) was noted for the within-subject effect. These results are similar to those found for GV and SL in that significant differences were found only within the trial comparisons.

Table 8.

ANOVA results for hip flexion velocity comparison by group and trial.

HFXVEL	**Between-Subjects Effects**		
	DF	**F**	**Sig**
Within+Residual	15		
Group	1	1.82	0.20
	Within-Subject Effects		
Within+Residual	45		
Factor1	3	3.11	**0.04**
Group by Factor	3	0.05	0.99

HFXVEL=hip flexion velocity; DF=degrees of freedom; F=f value; Sig=significance of F; bold face=significant difference at p<0.01.

Table 9 presents t-test data for hip flexion velocity by trial comparison. Results indicate significant differences between all trial combinations at p=0.00 (df=16).

Table 9.

T-test comparison results for hip flexion velocity.

Hip Flexion Velocity t-Test		
	DF	**Sig**
NW-AD	16	**0.00**
NW-ST	16	**0.00**
NW-STAD	16	**0.00**
AD-ST	16	**0.00**
AD-STAD	16	**0.00**
ST-STAD	16	**0.00**

DF=degrees of freedom; Sig=significance of F; bold face=significant difference at $p<0.01$; NW-AD=normal walking with cane retraction; NW-ST=normal walking with response to audible tone; NW-STAD normal walking compared with with cane retraction and audible tone; AD-STAD=walking with cane retraction compared with cane retraction and audible tone; ST-STAD=walking with audible tone compared with cane retraction and audible tone.

DISCUSSION

Kinematic characteristics of each subject were determined by evaluating his/her gait cycle and long-cane techniques during normal and tasked walking. Statistical analysis revealed significant differences for GV, SL, and hip flexion velocity within-groups for the different trial scenarios. However, no differences were found between TRAD and MOD groups for any of the dependent variables examined. Several variables, though not significant, displayed a large degree of variability. This was likely due to the differences in height, age, and degree of vision loss among subjects.

Traditional versus Modified Cane Technique

As previously described, subject grouping was determined by the long-cane techniques utilized by each subject as analyzed by a panel of O&M experts. Research suggests that MOD techniques could result in diminished path coverage, thereby resulting in a decrease of obstacle detection (2). However, results from the present study indicate no differences in wrist angular ROM or wrist angular velocity between subjects using accepted correct techniques and those utilizing so-called improper techniques. Wrist angle ROM for both groups was found to be 21.28°. Wrist flexion and extension velocities for the TRAD group were slightly higher; however, this result could be directly related to the marginally higher GVs found in the TRAD versus MOD group (127.69 cm/s vs. 117.87 cm/s) during NW.

The data between TRAD and MOD groups were not significantly different. However, the results suggest a contrasting pattern during NW. The angular ROMs for both groups are similar in magnitude for all four trials. This indicates that the overall gait mechanics for TRAD and MOD travelers are comparable. Flexion and extension angular joint velocities were greater for all trials in the TRAD group. This is expected if gait velocities for these subjects were also higher for all trials; however, this is not the case. These conflicting findings suggest travelers using TRAD techniques walk more confidently but decrease their GV through a reduction in either SL or SR.

GV for trials AD and STAD were found to be greater for the group using MOD technique (AD=88.58 cm/s, STAD=86.79 cm/s), yet knee and hip ROMs were nearly identical to that of the TRAD group. Hip and knee flexion and extension velocities were clearly lower for the MOD group for these trials, indicating a shuffling gait characteristic. Statistically, none of these components were found to be different, yet it is apparent there is some kinematic mechanism at work within the gait cycle to cause these intriguing results. It may be speculated that the increase in GV for the MOD travelers during trials AD and STAD is due to an increase in SR. However, without the benefit of a full-body, 3-D model assessing bilateral symmetry and center of mass deviation it is difficult to generalize these results with such a small subject sample.

Gait Velocity

Within-group GV results yielded a higher walking velocity during normal traveling compared to walking while responding to an audible attention-demanding task (NW=122.78 cm/s, ST=115.85 cm/s). This finding is in agreement with similar results found in studies where attention-demanding tasks were shown to decrease GV in elderly patients (1,3). The resulting decrease in velocity found during the present study indicates the difficulty visually impaired persons face when simultaneously traveling and responding to external stimuli. This attention-demanding response has also been shown to result in an increased potential for falls, since focus on path preview must now be divided between drop-off detection and the attention-demanding task.

Stride Length

SL was shown to decrease between normal and attention-demanding tasked walking (NW=95.75 cm, ST=92.22 cm). This result indicates an alteration in the subjects' gait cycle when faced with an attention-demanding task. This somato-sensory response can be viewed as a protective mechanism to allow the individual additional time to process the external stimulus while maintaining adequate drop-off detection awareness over the path of travel. Additionally, significant differences were found for SL between the cane retraction and audible tasked trials (AD=68.12 cm, ST=92.22 cm). The cane retraction can also be viewed as an attention-demanding task, in that the visually impaired subject must be constantly aware of drop-offs in his or her path of travel in order to prevent tripping or falling. This concern is evidenced by the distinctly lower values for SL found during trials AD and ST. Trials combining the simulated drop-off with the audible task were not found to be significant when analyzed. However, the SL values obtained during the trial STAD were calculated to be the lowest of the four trial scenarios.

Hip Flexion Velocity

Results from the paired t-tests for hip flexion velocity were found to be the most variable. All possible within-group trial comparisons yielded significant differences. These findings indicate that hip flexion plays a crucial role in determining how visually impaired persons adapt their gait during normal and tasked walking. Hip flexion velocity values were found to be lowest for the cane retraction trials (AD=-118.52 °/s) and audible attention-demanding tasked trials respectively (ST=-121.19 °/s). GVs and SLs were also lower during these trials than to those during NW.

The decreased hip flexion velocity values during trials AD and ST indicate the shuffling type gait exhibited by visually impaired persons when faced with an attention-demanding task during ambulation. Similar findings have been reported in a group of mobility travelers tested over an indoor obstacle course (8). These subjects were found to display altered gait mechanics when faced with the task of attending to the detection of path obstacles. One notable result from the present study concerning hip flexion velocity values was seen from the high velocities calculated during the combined cane retraction and audible task trials (STAD=-134.89 °/s). It was expected that hip flexion velocity values would be lowest for this scenario; however, these results proved to be significantly higher compared to the other trials, possibly suggesting that subjects are attempting to hurry the leg through the swing phase of the gait cycle in order to provide themselves additional stabilizing time during the double stance phase of the stride.

GV and SL values were also lowest for trial STAD (79.37 cm/s, 66.95 cm). This may indicate a completely different alteration in the gait mechanics of this group when faced with multiple tasks during traveling. Higher hip flexion velocities, combined with lower GVs and SLs, may indicate that the subjects were walking with a more pronounced, high-stepping pattern during the swing phase of the gait but decreased their SL as if stepping to avoid potential path obstacles. This gait alteration can be understood when examined from an O&M viewpoint. If the visually impaired person is faced with multiple attention-demanding tasks, it becomes difficult to maintain path preview through the use of the long cane alone. The division of the person's attention results in another somato-sensory "survival" response, which may account for this unique gait adjustment. The individual who cannot rely solely on long-cane mechanics to provide obstacle detection may unconsciously use this "high-stepping" technique as a method by which potential hazards may be detected with the feet.

CONCLUSION

Although the results from this study do not indicate statistically significant differences between groups of visually impaired travelers based on gait and long-cane mechanics, they do indicate significant alterations in the gait cycle based on the attention-demanding tasks this population faces during daily travel. One major concern of the long-cane user is the detection of drop-offs. Skill in detecting and managing drop-offs is learned through O&M training. In addition to training in the proper use of the long-cane, subjects are taught ways to recognize and utilize audible cues. These cues can be used to help orient the individual faced with difficult travel environments. The management of such hazards is also influenced by the level of confidence possessed by the individual. Additional studies examining attention-demanding and multi-tasking environments faced by travelers with visual impairment should be pursued in order to provide further insight on the effects of vision loss and its impact on the performance of O&M skills and other ADLs.

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