The effect of cane use on the compensatory step following posterior perturbations

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Received 6 January 2004; accepted 7 May 2004

Abstract

Objective. The compensatory step is a critical component of the balance response and is impaired in older fallers. The purpose of this research was to examine whether utilization of a cane modified the compensatory step response following external posterior perturbations.

Design. Single subject withdrawal design was employed. Single subject statistical analysis—the standard deviation bandwidth-method—supplemented visual analysis of the data.

Methods. Four older adults (range: 73–83 years) with balance impairment who habitually use a cane completed this study. Subjects received a series of sudden backward pulls that were large enough to elicit compensatory stepping. We examined the following variables both with and without cane use: timing of cane loading relative to step initiation and center of mass acceleration, stability margin, center of mass excursion and velocity, step length and width.

Results. No participant loaded the cane prior to initiation of the first compensatory step. There was no effect of cane use on the stability margin, nor was there an effect of cane use on center of mass excursion or velocity, or step length or width.

Conclusions. These data suggest that cane use does not necessarily improve balance recovery following an external posterior perturbation when the individual is forced to rely on compensatory stepping. Instead these data suggest that the strongest factor in modifying step characteristics is experience with the perturbation.

Relevance

Health professionals frequently prescribe canes for individuals with balance impairments. The results of this study suggest that a cane does not solve all of their balance problems.

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Keywords: Balance; Cane; Compensatory step

1. Introduction

Researchers have identified a variety of successful recovery strategies—including feet-in-place responses (such as ankle and hip strategies) as well as the compensatory step—which prevent a fall from occurring (Brown et al., 1999; Hsiao and Robinovitch, 1998). The compensatory step is a critical component of successful balance recovery following a loss of balance and is a common response among both younger and older adults (Brown et al., 1999; Hsiao and Robinovitch, 1998; McIlroy and Maki, 1996). The compensatory step response repositions the center of mass within a newly-established base of support, and is particularly useful for larger perturbations.

Laboratory studies utilizing the Postural Stress Test, which involves a sudden backward perturbation, have shown that the compensatory step in the backward direction is impaired in older fallers (Chandler et al., 1990; Wolfson et al., 1986). These studies found that while younger adults utilized 1 or 2 well-controlled steps only at the largest perturbation, older fallers utilized three or more steps even at smaller perturbation levels.
and the step responses were ineffective to prevent a fall in half of these older fallers. Indeed, video recordings of naturally occurring falls in older adults revealed that a step preceded half of the falls (Holliday et al., 1990). The step was a common response to a loss of balance, but for these older adults it was insufficient to prevent a fall.

Laboratory studies examining the mechanics of actual falls in younger subjects, revealed that subjects were more likely to fall backwards than forward or laterally following an external perturbation, and that they were most likely to impact the hip following a backward fall (Hsiao and Robinovitch, 1998). Direct impact to the hip following any fall from standing height has been shown to produce enough force to fracture the hip of an older adult (Robinovitch et al., 1991).

Canes are commonly prescribed for individuals with a history of falls in order to improve balance (Joyce and Kirby, 1991), yet little is known about the efficacy of cane use in balance recovery. Research has demonstrated that cane use improves static balance, as defined by a decrease in postural sway, under a variety of conditions (carrying a load (Jacobson et al., 1997), visual impairment (Jeka et al., 1996; Maeda et al., 1998), advanced aging (Maeda et al., 1998), hemiparesis (Milczarek et al., 1993), and vestibular deficits (Nandapalan et al., 1995)). However, only one study to date has examined the use of a cane following an external perturbation. Ashton-Miller and colleagues (1996) studied the effect of cane use on balance ability in healthy individuals and those with peripheral neuropathy. Individuals were instructed to maintain unilateral stance. Unexpectedly, the support surface rotated about a sagittal axis, inverting or everting the ankle. Cane use had a significant impact on successful performance of the task (defined as maintenance of unilateral stance) for both groups of subjects. Of considerable clinical importance, cane use by those with peripheral neuropathy resulted in a higher success rate than that achieved by healthy adults without use of a cane.

While cane use improves quiet as well as perturbed stance in the frontal plane (Jacobson et al., 1997; Jeka et al., 1996; Maeda et al., 1998; Milczarek et al., 1993; Nandapalan et al., 1995; Ashton-Miller et al., 1996), caution should be used in extrapolating these results to situations that require a compensatory step for balance recovery. Decreased postural sway during quiet stance has been shown to be unrelated to the ability to respond successfully to a large external perturbation (Owings et al., 2000). Thus, improvements in static postural stability (defined as decreased postural sway) provided by cane use may or may not result in improved balance recovery in a dynamic situation, such as occurs following a slip or trip.

Given the susceptibility of individuals to fall in the backward direction and the potential harm of a backward fall for an older adult, we explored whether use of a cane could improve balance responses to a backward perturbation. Specifically, we examined whether utilization of a cane modifies the compensatory step response following external posterior perturbations. We tested the null hypothesis that older adults who habitually use a cane for balance would not demonstrate altered balance responses following perturbation when using a cane, versus not using a cane. This hypothesis would be established by no relationship between mechanical loading of the cane and change in center of mass acceleration. The hypothesis would also be confirmed by equivalent stability margins and equivalent magnitudes and velocities of center of mass excursions with and without use of a cane. Also consistent with the hypothesis would be the use of equivalent step lengths and step widths with or without use of a cane.

2. Methods

2.1. Subjects

Four older adults (range: 73–87 years) with self-reported balance impairment completed this study. Only older adults who reported habitually using a cane for balance purposes were tested in order to control for novelty or potential attentional demands of using an assistive device for the first time (Wright and Kemp, 1992). Inclusion criteria included self-reported use of a cane for balance purposes for at least 3 months prior to the study, an ability to walk 150 feet with or without a cane, and an ability to stand at least 20 min. Exclusion criteria included a score on the Mini-Mental State Exam (MMSE) of less than 24 (Folstein et al., 1975) and cane dependence, defined as an inability to walk short distances without the cane. All participants gave informed consent indicating their willingness to participate in testing and an understanding of the protocol.

2.2. Physical examination

Each participant completed a health history questionnaire including medical and fall history and physical activity level, and a self-perceived balance ability questionnaire modified to indicate which activities involved cane use. In addition to screening for exclusion criteria, we used three clinical tests to characterize balance ability in our participants: (a) Berg Balance Scale (BBS) to assess balance while performing common daily activities, such as climbing stairs and reaching (Berg et al., 1989), (b) Dynamic Gait Index (DGI), which assesses an individual’s ability to modify gait in the presence of external demands (Shumway-Cook et al., 1997), and (c) a modification of the Clinical Test for Sensory Interaction in Balance (CTSIB), which systematically reduces or alters sensory information to assess the individual’s ability to
use sensory information to maintain upright balance (Anacker and Di Fabio, 1992). Four conditions were tested: condition 1 = eyes open/firm surface, condition 2 = eyes closed/firm surface, condition 3 = eyes open/foam surface, condition 4 = eyes closed/foam surface.

2.3. Data collection

The balance perturbation was created by use of the Postural Stress Test. The Postural Stress Test involves a sudden backward pull at the waist through a pulley-weight system (Wolfson et al., 1986). Vertical and horizontal forces under the feet were measured via strain gauges in each corner of the 46.4-cm × 50.8-cm force plate (Bertec Corp, Columbus OH, USA). In addition, a load cell located at the waist belt measured the force of the weights pulling on the subject, and strain gauges located at the distal shaft of the cane measured compressive load on the cane. Reflective markers were placed bilaterally over upper and lower extremity joint landmarks. Three-dimensional marker data were collected using a 5-camera Vicon motion analysis system (Vicon Motion Systems, Lake Forest CA, USA). Vicon software allows simultaneous, synchronized collection of both analog (600 Hz) and kinematic data (60 Hz). Trials were 6 s in length.

2.4. Procedure

Participants stood on a single force plate in a relaxed manner. They wore a belt at the level of the anterior-superior iliac spine (ASIS), which was connected via a cable and load cell to a pulley and weight system. They faced away from the pulley system, looking straight ahead with arms at their sides, and feet positioned comfortably. Initial foot and cane placement was marked and each trial began in this standardized position. Participants were instructed to maintain balance naturally, trying not to fall. No specific instructions concerning foot or cane movement were given, thus participants were free to move the cane after the start of the trial. The weights were released following a random 1–2 s delay after the start of the trial. A spotter stood behind each subject during all testing to prevent a fall.

A standard cane—instrumented with strain gauges to measure weight bearing through the cane—was adjusted to fit each individual so that cane height would not alter the response (Joyce and Kirby, 1991). For S1, equipment difficulty led to loss of strain gauge data, thus completion of the first cane step (thus, cane loading) was determined from the cane kinematics. Use of kinematic data to determine cane loading resulted in a systematic difference in timing (~10 ms) for S1. Since comparison was within subject, this difference had minimal impact on the results.

Subjects received 4–5 practice trials at increasing perturbation magnitudes (4–12% of body weight; 15.2 cm drop). The first two trials at the lowest perturbation magnitudes were performed without the cane and subsequent practice trials were performed with the cane held in the usual hand. The practice trials served two purposes. First, practice allowed subjects to familiarize themselves with the protocol both with and without the cane. The greatest changes in balance response following external perturbations have been found to occur within the first six trials (Maki and Whitelaw, 1993); thus, to compare the cane and no cane conditions in the absence of perturbation novelty, the practice trials were not analyzed. Secondly, the practice trials allowed determination of a perturbation magnitude that would consistently elicit a backward compensatory step. After the practice trials, the magnitude of perturbation used throughout testing of an individual remained the same.

2.5. Research design

Single subject withdrawal design (A–B–A–B) was employed to examine the effects of cane use on the compensatory step response. In order to test generalizability of cane use in individuals with balance difficulty, the method of direct replication was utilized (Barlow and Hersen, 1984). In order to control for testing order effects, two designs were counterbalanced between subjects: A–B–A–B and B–A–B–A, where A refers to conditions in which the cane is used and B refers to conditions in which the cane is not used.

Cane condition (i.e., with and without a cane) was tested in a blocked manner. In order to get a stable response under each cane condition at least 3 data points from each condition are necessary (Barlow and Hersen, 1984). Thus, 3–4 trials of the perturbation were tested under each condition depending on the endurance of the individual. The minimum number of trials was 12 and the maximum was 16 after the practice trials.

2.6. Dependent variables

2.6.1. Cane use characteristics

In order to understand how the cane is used to control the balance response we examined the timing of cane loading (i.e., increased weight bearing through the cane following lifting and repositioning of the cane) relative to step initiation, as well as the potential contribution of the horizontal component of the cane force acting to slow the backward acceleration of the center of mass. Since the contribution of the feet is unknown once the individual steps off the force plate, we do not know the sum of the ground contact forces. Therefore, the magnitude of the cane force cannot be put in context with the magnitude of foot force. Given that limitation, we considered simply whether the cane could, or could not,
Contribute a restorative force by determining the angle of the cane (from cane kinematics) at the time of increased cane loading (determined from the cane strain gauge). If the cane were repositioned such that it angled forward (cane tip ahead of the body), the horizontal reaction force at the cane tip would contribute a force increasing the backward acceleration of the center of mass (CoM), thus contributing to destabilization. However, if the cane were repositioned such that it angled backward (cane tip behind the body), the cane horizontal reaction force would act anteriorly and would contribute a force to slow the backward acceleration of the CoM, thus contributing to stabilization. In order to assess whether the cane force contributed to the mechanical solution of balance recovery, we examined the temporal association between the change in backward acceleration of the CoM and anteriorly directed cane reaction forces. Cane force loading and a change in the center of mass acceleration from posterior to anterior were considered to be temporally associated if the two events occurred within a time period of 30–100 ms. Outside this time period other confounding influences act upon the CoM acceleration.

2.6.2. Stability margin

Stability margin (SM) was defined as the distance—in the direction of pull (i.e., posterior)—between the vertical projection of the CoM and the posterior margin of the base of support (BoS). The BoS was comprised of bilateral feet (heel markers), or unilateral foot (heel marker) and cane (marker), depending on condition and which combination provided the most posterior edge of the BoS (Fig. 1). A larger stability margin indicates greater separation between the BoS and CoM, thus greater stability.

2.6.3. Center of mass (medial–lateral excursion and velocity)

Center of mass was calculated based on a 13- or 14-segment model (depending on cane or no-cane condition), including feet, shanks, thighs, pelvis, trunk, head/neck, upper arms, lower arms, and cane. Only medial–lateral displacement and velocity were analyzed. CoM medial–lateral excursion following the first step was calculated by subtracting CoM medial–lateral position at the time of first step touchdown from the initial position, averaged over 50 ms prior to perturbation. Recent studies have found that older adults have difficulty controlling lateral stability when executing compensatory steps in response to anterior–posterior perturbations as evidenced by an increase in the frequency of laterally-directed compensatory steps (McIlroy and Maki, 1996). Therefore, smaller medial–lateral excursions were considered markers of better balance ability.

2.6.4. Step kinematics—length and width

Step length was defined as the anterior–posterior distance between the initial position of the toe marker and its position at foot contact. Step width was defined as the medial–lateral distance between the position of the left and right ankle markers at foot contact. A longer or wider step increases the moment arm between the BoS and vertical projection of the CoM; thus, increasing the stabilizing torque. A longer or wider step was considered a marker of better balance.

2.7. Data analysis

In SSD the primary method of data analysis has been visual inspection of the data. The standard deviation
band-method is a semi-statistical adjunct to visual analysis (Ottenbacher, 1986). In this approach, the mean and standard deviation of the baseline data are calculated and lines are placed at two standard deviations above and below the baseline mean. A significant effect is noted if at least two data points fall outside of this band during the subsequent intervention phase (Ottenbacher, 1986). In this study, we adopted a modified bandwidth criterion. The average and standard deviation of the baseline (i.e., initial) condition for each variable were calculated for each subject. A significance criterion of 1.5 standard deviations from the baseline average (approximating a significance level of $p < 0.1$) was selected a priori as appropriate for special populations (Burton and Miller, 1998). While this criterion is generous in its potential to reveal significant condition differences, failure to meet this criterion provides even greater support for the null hypothesis.

3. Results

3.1. Subject characteristics

All of the subjects reported primarily using the cane outside or on stairs; none of the subjects reported using the cane indoors. No information regarding specific training with the cane was available.

S1 was an 83-year-old male who had used a single point cane for a year. His balance impairment was related to peripheral vestibular dysfunction. In addition, he reported he had arthritis. He scored 34/56 on BBS and 15/24 on DGI indicating risk for falls. He had difficulty on M-CTSIB conditions 2–4. S2 was a 73-year-old female who had used a narrow-base quad cane for the most part outside for 5 months. She reported that she had arthritis, back pain, adult-onset diabetes, and had had a stroke with minimal residual weakness 1.5 years prior to testing. She scored 46/56 on BBS and 17/24 on DGI indicating risk for falls. She had difficulty with conditions 3 and 4 of the M-CTSIB. S3 was a 76-year-old male who had experienced two falls in the previous year. He primarily used the cane for increased confidence and protection, and had had a stroke with minimal residual weakness 1.5 years prior to testing. She scored 46/56 on BBS and 17/24 on DGI indicating risk for falls. He had difficulty with conditions 3 and 4 of the M-CTSIB. S3 was a 76-year-old female who had used a single point cane for approximately one year. She primarily used the cane for increased balance confidence. She reported that she had had spine surgery and vertigo, had tinnitus and Sjogren’s Syndrome. She scored 51/56 on BBS and 22/24 on DGI indicating low risk for falls. She had difficulty with condition 4 of M-CTSIB.

3.2. Perturbation characteristics

The perturbation magnitude used to elicit a step was 10–12% of each individual’s body weight with an average peak load of 261.3 N (range: 206.8–288.2 N) and an average impulse of 24.1 Ns (range: 19.0–27.8 Ns).

3.3. Cane use

No participant loaded the cane prior to initiation of the first compensatory step. Fig. 2 presents two exemplar patterns of cane loading following perturbation. The top figure (S2) demonstrates a trial in which the cane was loaded, though loading occurred after the initiation of the first two compensatory steps. The bottom figure (S4) demonstrates a trial in which the cane was not loaded following the perturbation. S2 and S3 always loaded the cane after the second step was initiated; thus, the cane force could not influence the first compensatory step. S4 did not take any cane steps. The cane remained in front of her. S1, on the other hand, moved the cane backwards planting it prior to initiation of the second compensatory step in three of six cane trials and after initiation of the second step (by nearly 400 ms) in one trial; the cane remained stationary in the
other two trials. In sum, no participant moved the cane as a ‘first step’ in response to the posterior perturbation.

We also examined the contribution of cane loading to slowing the backward acceleration of the CoM. First, we determined the angle of the cane at the time of increased loading. In fewer than 25% of all the cane trials (6 of 26; 3 of the 6 were from S1) was the cane positioned to contribute to slowing of the backward acceleration of the CoM. In one-third of these trials \( n = 2 \), the center of mass was already accelerating forward, and so the cane reaction force did not help slow the backward acceleration of the CoM. In fact, posterior positioning of the cane and the timely association of cane loading with a change in the backward acceleration of the CoM occurred in only one of all cane trials (a trial from S1).

3.4. Stability margin

With the exception of S1, there was no clear evidence to demonstrate an effect of cane use on the stability margin. For S1, half of the trials in which he used a cane demonstrated a significantly larger (i.e., outside the 1.5 SD bandwidth) stability margin than the no cane trials (Fig. 3). Neither S2 nor S4 showed a significant change in stability margin under either condition. S3 did demonstrate a significant increase in stability margin across trials, but independent of cane condition. That is, the stability margin increased above the 1.5 SD bandwidth during the cane trials, but did not fall below this threshold during the no-cane trials. Stability margin for the second step was highly variable for all participants and showed no significant cane or trial effect.

3.5. Center of mass medial–lateral excursion and velocity

No clear effect of cane use on CoM excursion in the medial–lateral direction was observed. CoM excursion for S1 for the baseline condition (no cane) was highly variable with a range of the standard deviation four times greater compared to other participants (Fig. 4). For S1, there was no effect of cane, although CoM excursion tended to decrease across trials. There was a significant trial effect for both S2 and S3 with CoM excursion increasing above the 1.5 SD bandwidth across trials but independent of cane use. CoM excursion was stable for S4 and did not change with either cane use or repeated trials.

The CoM medial–lateral velocity behaved in much the same way as CoM excursion. CoM velocity for S1 was highly variable, and no difference was noted across trials or conditions. CoM velocity for both S2 and S3 increased significantly (above the 1.5 SD bandwidth) across trials, but independent of cane condition. Interestingly, CoM velocity of S4 tended to decrease after the initial exposure to the perturbation.

3.6. Step kinematics

Results from the four participants revealed no significant effect of cane use on the step length of the first or second compensatory step. Examination of the data revealed subject-specific responses to perturbation but no effect of cane use on step length (Fig. 5). For example, S1 had high variability in first step length across conditions with no relationship to cane use. S2 exhibited significantly longer step length after the first two conditions, but not as a result of cane use. There is some indication that the cane may have initially aided S3 in achieving a significantly longer step; however, subsequent step length increases were not dependent on cane use. Step length for S4 remained consistent across conditions revealing no effect of cane use. The second step was highly variable for all subjects with no clear effect of cane use.

As with step length, cane use did not alter step width. Neither S1 nor S4 showed any effect of trial or condition on first step width. Both S2 and S3 exhibited an increase in...
in step width across trials, but not as a result of cane use: step width increased significantly with repeat exposure to the perturbation. In the case of S2 step width stabilized after the first set of cane trials, while S3 showed continued variability. High variability was again observed in the second step, although unrelated to cane use.

4. Discussion

Health care professionals commonly prescribe canes for individuals with balance difficulties. There is sufficient evidence to support this practice for static balance as cane use has been found to improve postural stability during quiet stance (Jacobson et al., 1997; Jeka et al., 1996; Maeda et al., 1998; Milczarek et al., 1993; Nandapalan et al., 1995). In addition, studies have revealed that cane use is efficacious during gait (Kuan et al., 1999) and maintenance of unipedal stance following a support surface perturbation (Ashton-Miller et al., 1996). However, no studies have examined cane use in balance recovery requiring compensatory stepping, even though the compensatory step has been shown to be a critical component of the balance response and is impaired in older fallers (Chandler et al., 1990; Wolfson et al., 1986). As in previous studies (McIlroy and Maki, 1996; Chandler et al., 1990; Wolfson et al., 1986), the participants in this study used multiple short steps, frequently directed laterally, to recover balance following an external posterior perturbation. These data suggest that cane use by individuals with balance impairment does not improve balance recovery following external posterior perturbation when the individual is forced to rely on compensatory stepping. Instead these data suggest that the strongest factor in modifying step characteristics is experience with the perturbation, not cane use.

In order to quantify the effect of cane use, we employed a single subject research design. The range of balance ability of the individuals tested was fairly broad based on clinical balance testing. The four participants in this study are typical of community-dwelling older adults in terms of comorbidities, any of which may impact balance ability. They reported having arthritis and/or back pain (S1, S2, S3), vestibular dysfunction (S1, S4), diabetes (S2, S3), and stroke (S2). Relative to the other participants, S1 was extreme in terms of fall risk. However, we did not note any differences in balance reactions for this subject. Based on cane use, S1 had the best possibility for modifying the balance
response with the cane because of cane placement in 4 of 6 trials after the 1st or 2nd step. Each of the individuals in this study had used the cane for at least 5 months prior to testing, so lack of experience did not influence their ability to use the cane. None of the participants were dependent on the cane: they reported using the cane primarily outdoors and on uneven surfaces.

A significant finding of this study is that the cane was rarely used as a mechanical aid to modify balance recovery to a backward perturbation. While we may not expect the cane to be the “first step” following an external perturbation, it is possible given that it is the least weighted support and the arms are activated early in the balance response (latency similar to that of the ankle musculature; Maki and McIlroy, 1997). It is also possible for the cane to be lifted quickly in the forward direction to counterbalance the backward perturbation. Examination of the video recordings showed no evidence of this type of compensatory strategy. When not using the cane, subjects frequently raised their arms in front of them, sometimes as high as the shoulder. When using the cane, subjects exhibited reduced arm elevation of the cane arm. These observations are similar to those of Bateni et al. (2004) who found that compensatory grasping following balance perturbations was reduced when the subject held an object (cane or canetop).

None of our participants loaded the cane prior to the first step. More importantly, however, might be whether the cane is used before the 2nd step. When we see multiple steps in older adults, the mechanical explanation is that the first step is insufficient in creating a counterbalancing force to stop the CoM acceleration. Thus, additional steps are employed. It is reasonable to think that the cane might be integrated into the midst of the balance response, if not before the first step. The next most effective application of the cane would be before the 2nd step. S1 did, in fact, plant the cane prior to the 2nd step in 3 of 6 cane trials and after the 2nd step in one trial. This is an example of incorporating the cane as a third weight-bearing structure to aid balance in response to a backward perturbation.

It is clear from previous research that a cane provides more than just mechanical assistance. Jeka and Lackner found that the additional sensory cues provided by a cane, in the absence of mechanical support, improved postural stability (Jeka and Lackner, 1994, 1995). Thus, we also examined whether cane use, regardless of timing of cane loading, was associated with altered step characteristics. Based on the relationship between center of mass and base of support, a smaller excursion of center of mass would result in a reduced threat to balance (McIlroy and Maki, 1996). Cane use did not affect center of mass excursion. In addition to controlling the position of the center of mass, the individual must also control center of mass velocity, as greater velocity requires greater slowing forces. There was no effect of cane use on medial–lateral center of mass velocity. Combining the horizontal position of center of mass and base of support resulted in a variable termed stability margin. A larger stability margin indicates greater separation between the projection of the center of mass and edge of the base of support in the direction of the perturbation, thus greater stability. Again, we did not find that cane use resulted in a larger posterior stability margin.

Cane use also had no effect on the spatial characteristics of the compensatory steps. Following an external perturbation, a compensatory step establishes a new base of support contributing to stabilization of the individual. By increasing step length or step width the moment arm between the edge of the base of support—the point of force application—and the horizontal distance between the center of mass is increased, thus increasing the stabilizing torque in the anterior–posterior or medial–lateral direction. We did not find step length or width to increase as a result of cane use.

Although cane use and the additional sensory information it provides did not significantly alter characteristics of the compensatory step, repeated exposure to the perturbation did affect the responses of two of the four subjects. Step characteristics for both S2 and S4 improved across trials: both step length and width increased. S4 also exhibited a larger stability margin with repeated exposure to the perturbation. All of these changes are indicative of improved stability. In addition, S2 and S4 exhibited greater medial–lateral center of mass excursion and velocity following repeated exposure to the perturbation, independent of cane use. Such changes are typically interpreted as decreased stability. However, if we examine the results in light of similar findings of Wolf and colleagues (1996) then a different interpretation is warranted. Wolf and colleagues found that a Tai Chi intervention resulted in increased postural sway during quiet stance, although these same individuals had a reduced risk of falling. Consistent with the findings of Wolf and colleagues, repeat exposure to the perturbation may have led to improved balance confidence such that two individuals allowed greater CoM excursion and velocity.

The present results suggest that cane use did not contribute to the mechanical solution of balance recovery following backward perturbations. It may be the case that cane use allows the individual to withstand larger perturbations before resorting to a compensatory step. Because we adjusted the perturbation magnitude to ensure that a step would be elicited, the experimental design does not allow us to answer this question. We have only indirect evidence that cane use may result in lower fall rates in older adults (Pine et al., 2002). Pine and colleagues found equivalent fall rates in older adults who used a cane versus older adults who did not use a cane, even though these individuals were more frail at baseline testing and more likely to develop mobility difficulties during the 2-year follow-up.
We must also consider that the standardized initial cane placement and the direction of perturbation may have affected cane use during balance recovery. The standardized placement of the cane prior to each trial restricted participants from adjusting to anticipated perturbations. In addition, it may be more natural to respond with the cane in the forward direction since individuals are accustomed to moving the cane forward during gait. Bateni et al. (2004) did find that during the initial balance response subjects loaded the cane when falling forward, but unloaded the cane when falling backward. Nevertheless, a backward perturbation is most likely to result in a fall (at least in younger adults); thus, it is important to examine how we might alter the compensatory step in the backward direction to make the balance response more effective (Hsiao and Robinovitch, 1998; Robinovitch et al., 1991). The cane may become part of a multi-limb strategy in recovery of balance in the backward direction with the goal being to reduce the number of steps taken before balance is recovered. The fact that the spatial characteristics of the compensatory step improved in two subjects suggests that the compensatory step may be modifiable in some individuals with repeated exposure to large external posterior perturbations.

5. Conclusion

As health professionals we frequently prescribe canes for individuals with balance impairments. The results of this study suggest that we do not solve all of the balance problems of these individuals by simply giving them a cane. Knowing how to stand and walk with a cane does not translate into using the cane to improve recovery of balance using a backward compensatory step. The results do suggest that short-term exposure to large perturbations result in improved step length, step width, and stability margin in some individuals with balance impairment. In order to effectively retrain the ability to recover balance using compensatory stepping, we may need to expose individuals to large perturbations in the context of cane use. It is not known whether this type of training will transfer to a naturally occurring loss of balance. Further study into the effectiveness of training balance recovery while using a cane is warranted.

References


