Sensory Training Effects on Obstacle Avoidance in Healthy Older Adults

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Abstract:
The purpose of this study was to examine the effectiveness of a five-day balance training program on obstacle avoidance measures in a group of healthy older adults. A 2 × 3 repeated measures MANOVA revealed no significant differences between three groups of older adult participants. A follow-up paired t-test revealed a significant difference between the control group and the experimental and walking control groups for pre- and post-tests. These results suggest that a five-day program is ineffective for improving measures of toe clearance, heel clearance, horizontal shear, and gait velocity, but may be beneficial
in delaying a loss in obstacle crossing speed in healthy older adults.
Keywords: Balance, exercise, gait, elderly

Article:
Balance is an essential component of almost all activities of daily living and is important for the maintenance of an active and functional lifestyle. As individuals age, they are often confronted with serious declines in motor functioning that impair their ability to perform simple activities of daily living that require efficient postural control. Older adults are sustaining falls due to these dramatic declines in postural control. In 1998, about 9,600 people over the age of 65 died from fall-related injuries (National Center for Health Statistics, 2000). It has been estimated that 25%-30% of older adults sustain a fall each year (Sattin, 1992). Ninety percent of hip fractures that occur in older individuals are the result of a fall (Grisso, Kelsey, & Strom, 1991). Additionally, tripping over obstacles has been documented to account for 30%-50% of falls in community-dwelling older adults (Lord, Ward, Williams, & Anstey, 1993). By the year 2020, the cost of fall-related injuries is expected to reach $32.4 billion dollars (Englander, Hodson, & Terregrossa, 1996). As it is estimated that the population of older adults in this country over the age of 65 will increase to 80 million by the year 2050 (United States Bureau of the Census, 1995), falling and factors associated with gait are a major healthcare concern.

Stepping over obstacles during walking is an everyday activity that older adults must be able to perform safely in order to maintain functional ability. Walking requires a significant amount of balance to keep the center of mass within the base of support, as that base of support is continually moving. This can be a challenge to the older adult who may have decreased sensory system capabilities, including impairments in visual sense, vestibular functioning, and proprioceptive sensation. As the postural control system is controlled by these three sensory systems, loss of function in one, or all, may lead to balance impairments. Thus, it becomes clear that any improvement in sensory integration may improve functional capabilities in older adults (Hu & Woollacott, 1994). Retraining of sensory functioning through a progressive training program involving simple and safe activities that can be done in the home may lead to improvements in sensory integration. Thus, the purpose of this exploratory investigation was to determine whether indirect manipulation of the sensory inputs necessary for dynamic balance could effect change in the performance of these sensory structures, allowing for a more efficient and effective obstacle crossing strategy.

Researchers have suggested that older adults adopt a more conservative, or cautious, walking pattern when faced with an environmental challenge, such as stepping over an obstacle (Hsieh-Ching, Ashton- Miller, Alexander, & Schultz, 1991; Rosengren, McAuley, & Milhalko, 1998). This more conservative strategy is characterized by a slower gait speed when approaching an obstacle, slower crossing speeds, and increased toe and heel clearance (Hsieh-Ching, Ashton-Miller, Alexander, & Schultz, 1991; Rosengren, McAuley, & Milhalko,1998; Winter, 1991), which may be indicative of losses in sensory function with age. A slower obstacle crossing speed is dangerous to an older individual, as that individual is in a period of single-limb support, which is a state of inherent instability. Thus, although adopting a more conservative stepping strategy may be an often-used compensatory behavior in older adults, it may actually lead to more obstacle contact and falls. Additionally, decreases in toe and heel clearance and obstacle crossing speed not only lead to falls during the stepping action, but also to a loss in functional ability and decrease in gait and mobility.

Older adults often encounter obstacles when walking, such as curbstones. It is important, therefore, to determine whether improvements in sensory function result in increased postural control when faced with changing environmental conditions. A static sensory training program designed to manipulate the three sensory systems important for postural control has been shown to improve static (stationary) balance in older adults (Hu & Woollacott,1994). Balance training is sensitive to the specific types of balancing activities to be accomplished. Therefore, it is hypothesized that for dynamic balance during the stepping action over an obstacle to be improved in older adults, a dynamic form of sensory training must be used to improve function.

METHODS

The older adult participants for this study were drawn from the surrounding area and independent living facilities in a mid-sized southern community. Following IRB approval, thirty healthy, community-dwelling older adults with a mean age of 82.5 years (± 6.7 years) were recruited for participation in this study (Table 1). The participants consisted of 25 female and five male participants. All participants were able to ambulate at least 200 feet without the use of an assistive device and were free from any central nervous system disorders or significant orthopedic diseases in the trunk or lower extremities. Conditions such as arthritis or osteoporosis did not disqualify individuals from participation in this investigation. In addition, all participants were self-screened for pre-existing balance disorders through the use of a survey instrument. Following an explanation of all the factors related to the current investigation and the protection of their rights as participants, an informed consent was signed.

Participants were randomly assigned to one of three groups (n = 10/ group): experimental group (EG), walking control group (WC), control group (C). During the training period, the experimental group (EG) took part in a dynamic multisensory training program for five consecutive days, which has been shown to be an effective period of time for alterations in sensory performance (Brandt, Buchele, & Krafczyk, 1986). This program consisted of walking practice (48 trials) with multi-sensory manipulation. Participants in the control group I (C) performed only normal activities of daily living and were not given any specific training exercises. Participants in the walking control group (WC) participated in the same number of walking trials as the experimental group, without sensory manipulation. Participants in the walking control group (WC) were asked to walk 48 trials to minimize the relationship of potential increases in strength to changes in obstacle clearance ability.

Pre- and post-testing procedures involved stepping over a simulated curbstone measuring 12 centimeters in height and ten centimeters in width. Both the control and experimental groups participated in identical test sessions before and after the consecutive five-day period. All pre- and post-test kinematic measurements of the foot and lower extremities were conducted in the Applied Neuromechanical Research Laboratory on the University of North Carolina at Greensboro campus. The Motion Monitor 3-Dimensional Motion Analysis System[1] was used to measure changes in joint position and obstacle clearance strategies during a gait cycle. The Motion Monitor consists of a modified Flock of Birds (Ascension Technology Corp., Burlington, VT) six-degree of freedom magnetic tracking system with a sampling frequency of 100 Hz and specialized software for the calculation of body segment and sensor positions during movement. This system is used to determine the position and orientation of the movable sensors relative to a fixed transmitter outside of the electromagnetic field. Each sensor of the system reports six degrees of freedom (global coordinates, local axes orientation) within the space defined by the electromagnetic tracking device. The Motion Monitor System has been shown to be reliable to within .07 cm (Ascension Technology Corp., Burlington, VT). From this information, three-dimensional data providing information about body segment position and segment speed in relation to the simulated curbstone. Kinetic measurements were acquired using a non-conducting type 4060-NC Bertec force plate. An AM-6700 amplifier with a four-pole filter and 100 Hz cutoff value to receive and filter the data was used. The data were transferred to a lab computer and analyzed using a customized computer analysis package (Visual Basic). Pre-testing and post-testing consisted of examining the following kinematic measures: toe clearance, heel clearance, horizontal sheer force, obstacle crossing speed, and gait velocity.

TABLE 1. Participant Characteristics

	Experimental Group (EG)	Walking Control Group (WC)	Control Group (C)
	n = 10	n = 10	n = 10
Age	86.4 (± 7.1)	84.7 (± 4.9)	77.1 (± 5.0)
Gender	9 females/1 male	9 females/1 male	7 females/3 males

Toe Clearance
Toe clearance was determined as the absolute distance between the big toe of the participant and the leading edge of the simulated curbstone as the big toe passed over the leading edge. Toe clearance was calculated by obtaining the position of the toe in the Y-plane and the position of the top edge of the curb in the Y-plane and taking the difference of the two measures to obtain the absolute distance. The mean toe clearance was obtained by averaging across five trials.

Heel Clearance
Heel clearance was defined as the absolute distance in centimeters between the heel of the lead foot and the top back edge of the simulated curbstone at foot contact. Heel clearance was calculated by obtaining the position of the heel on the Z-plane and the position of the trailing edge of the object in the Z-plane and taking the difference to obtain the absolute distance. The mean clearance difference was determined following completion of all five trials.

Horizontal Shear Force
Horizontal shear force (braking force) was defined as the peak horizontal ground reaction force normalized to body mass in kilograms at the instant of heel strike with the ground following the step.

Crossing Speed Over the Simulated Curbstone
Crossing speed over the obstacle was defined as the time in milliseconds required for the big toe of the lead foot to cross the obstacle. It was examined by determining the distance the foot travels from the lead edge of the obstacle until it crossed the far edge of the simulated curbstone. The mean crossing velocity was determined by averaging across the five trials.

Gait Velocity
Gait velocity was defined as the average velocity attained by participants during the eight-foot walk prior to crossing over the obstacle. Gait velocity was obtained by using a standard VHS video camera placed perpendicular to the walkway and eight feet from its lateral edge. Average velocities were obtained by transferring the video data to a Peak Performance Motion Analysis system (Peak Performance Technologies, Boulder, CO) and digitizing the hip of each participant throughout three full strides of the walking trial. Gait velocity was recorded as the mean velocity over five recorded trials.

SENSORY TRAINING PROTOCOL/INTERVENTION
Experimental Group (EG)
During this intervention, the participants were instructed to walk at a preferred speed on both an eight-foot long firm surface and an eight-foot long, medium density foam surface. Participants were instructed to perform six walking trials of each sensory training condition (Table 2) over a distance of eight feet with a ten-second rest period in between each trial. These included trials in which the participant was asked to walk with eyes closed,

head tilted, or over firm/unstable surfaces during the duration of the trial. The alterations in sensory inputs were adopted from previous research successfully examining the effects of sensory training (Hu & Woollacott, 1994). Participants were instructed to sway as little as possible to control their postural stability through the use of sensory control structures. Each participant wore a standard physical therapy gait belt approximately at waist level during the protocol. The researcher walked beside them holding onto the gait belt to prevent a total loss of balance during the protocol.

Walking Control Group (WC)
Following pre-testing, individuals met with the researcher in their homes during the length of the intervention. These participants, however, were asked to perform 48 walking trials on the eight-foot, firm surface walkway without any sensory modifications. They walked at their self selected comfortable pace for each trial in an effort to mimic their individual normal walking velocity.

Control Group (C)
Following pre-testing, these individuals were instructed to perform their normal activities of daily living without any specified walking or sensory intervention. There were no in-home visits by the researcher during the intervention period.

RESULTS
Multivariate Statistical Analysis
A 2 × 3 (Time × Group) repeated measures multivariate analysis of variance revealed no significant differences between the experimental group (EG) and the two control groups (WC & C) (Wilks' Lambda = 1.61, $F_{12,24}$ =.12) (Table 3). As the repeated measures MANOVA revealed no significant differences between groups, an exploratory analysis for each variable was performed to determine whether any significant effects for individual factors were masked. The results revealed no significant differences between pre and post-test scores for measures of toe clearance, heel clearance, horizontal shear, and gait velocity. Significant pre and post-test differences for crossing speed were found ($F_{2,\,27} = 6.27$, $p = .006$). Follow-up paired t-tests demonstrated a significant effect for the non-intervention control group for the measure of crossing speed, as their crossing speed decreased at posttest ($t_9 = 2.60$, $p = .03$). The results (Figure 1) demonstrate a slight improvement in crossing speed in the experimental group and maintenance of ability in the walking control group.

TABLE 2. Sensory Training Conditions

Condition 1:	Eyes open, head neutral, walking on a firm surface
Condition 2:	Eyes open, head tilted, walking on a firm surface
Condition 3:	Eyes closed, head neutral, walking on a firm surface
Condition 4:	Eyes closed, head tilted, walking on a firm surface
Condition 5:	Eyes open, head neutral, walking on a 5.08 cm. thick foam surface
Condition 6:	Eyes open, head tilted, walking on a 5.08 cm. thick foam surface
Condition 7:	Eyes closed, head neutral, walking on a 5.08 cm. thick foam surface
Condition 8:	Eyes closed, head tilted, walking on a 5.08 cm. thick foam surface

DISCUSSION
The goal of this exploratory investigation was to determine whether specific factors associated with stepping actions in a group of older adults could be improved through the implementation of a progressive dynamic sensory training protocol that stressed sensory structures necessary for safe and efficient stepping. The results of this investigation revealed no significant changes between pre-test and post-test scores for four of the five independent variables that were examined: toe clearance, heel clearance, horizontal shear, and gait velocity. It was hypothesized that measures of toe clearance and heel clearance would decrease following the sensory training protocol due to an increase in sensory functioning. This decrease in clearance distance would be indicative of a more efficient and stable crossing pattern, thus reducing the risk of contact with the obstacle. Horizontal shear was expected to increase due to a hypothesized increase in crossing speed. Additionally, it was hypothesized that gait velocity would increase due to enhanced sensory integration.

Significant differences were found between the pre-test and post-test scores for crossing speed for the control group (C). The control group demonstrated a slower crossing speed than the experimental and walking control groups following the intervention. Although probability levels were set at .05, this outcome may be the result of chance occurrence. Crossing speed did increase in the experimental group; however, the amount of change was not statistically significant. This suggests that, with several design modifications, such as an increased period of time to practice, speed may be improved through this type of intervention. As previously discussed, the actual decrease in crossing speed in the nonintervention group suggests that a sensory training protocol may maintain function and obstacle avoidance strategies in older adults. Although an improvement in function was not demonstrated, a delay in the onset of functional impairments related to crossing speed may allow for the maintenance of independence in healthy older adults.

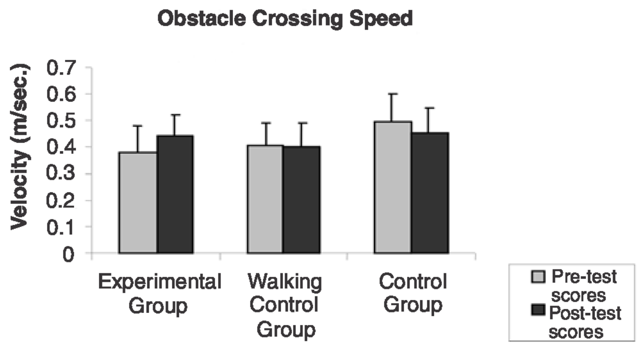
TABLE 3. Means and standard deviations of pre-test and post-test measures for toe clearance, heel clearance, crossing speed, gait velocity, and horizontal shear for the experimental group (EG), walking control group (WC), and control group (C)

GROUP MEANS AND STANDARD DEVIATIONS

Dependent variable	*Group*	*Mean*	*SD*
Toe clearance (pre)	EG	3.54 (cm)	2.11 (cm)
	WC	4.09	2.74
	C	4.26	3.14
Toe clearance (post)	EG	4.73	2.35
	WC	4.71	2.93
	C	4.21	2.50
Heel clearance (pre)	EG	5.85 (cm)	3.35 (cm)
	WC	4.94	2.88
	C	7.59	3.47
Heel clearance (post)	EG	5.89	2.49
	WC	4.98	2.46
	C	6.62	2.12
Crossing speed (pre)	EG	.380 (m/sec.)	.100 (m/sec.)
	WC	.402	.090
	C	.494	.105
Crossing speed (post)	EG	.442	.082
	WC	.398	.093
	C	.452	.095
Gait velocity (pre)	EG	.832 (m/sec.)	.193 (m/sec.)
	WC	.832	.201
	C	1.00	.166
Gait velocity (post)	EG	.868	.179
	WC	.812	.170
	C	1.01	.204
Horizontal shear (pre)	EG	116.13 (Newtons)	35.80 (Newtons)
	WC	101.45	53.79
	C	129.41	52.69
Horizontal shear (post)	EG	96.51	23.26
	WC	114.28	48.78
	C	98.65	31.01

Crossing speed over the obstacle by the lead foot was significantly slower than that reported in previous investigations (Chen, Ashton- Miller, Alexander, & Schultz, 1991; Rosengren et al., 1998). This result may be due to the age of the participants in this study. The average age of the participants in previous investigations was 73.1 and 71.1 years respectively (Chen et al., 1991; Rosengren et al.,1998). Rosengren and colleagues (1998) examined measures of gait and step characteristics in a group of older adults. In their investigation, obstacles of differing heights were placed in the path of older individuals and stepping strategies were examined. Interestingly, measures of crossing speed in this current investigation were similar to those measures obtained for the obstacle of greatest height (40 cm.) in previous investigations (Rosengren et al., 1998). Crossing speed for the obstacles at lower heights was significantly higher than that obtained in this investigation. Thus, although relatively healthy, the older adults in this investigation may have been slower and more cautious when attempting to step over the obstacle due to greater decrements in their overall functioning. Crossing speed has been shown to decrease with an increase in age, thus, the older an adult is, the more slowly they cross an obstacle due to age-related factors other than sensory functioning. Measures of gait velocity were also consistent with previous investigations (Chen et al., 1991; Winter, 1991).

FIGURE 1. Pre-test and post-test scores for measures of crossing speed



When examining the specific results for each group, it is clear there were no significant differences between the pre-test and post-test scores. Scores for measures of toe clearance and heel clearance in the experimental group actually increased following the intervention. This may be related to the specific activities the participants performed during the intervention. During the foam walking trials of the sensory training activities, the participants often exaggerated their stepping during the walking trials in an effort to avoid tripping on the foam surface. This exaggeration in the stepping action may have resulted in a similar movement being performed during the post-test, thus accounting for increases in toe and heel measures over the obstacle.

Horizontal shear, a measure of the ground reaction force following the stepping action, decreased in the experimental and control groups, but actually increased in the walking control group. As there were no significant changes in measures of toe clearance, heel clearance, and crossing speed, an increase in horizontal shear would not be expected. A decrease in toe clearance and heel clearance would reflect a less conservative crossing strategy by using a decreased angle of clearance over the obstacle. These changes would impact the resultant horizontal shear. A “shallower” angle over the obstacle with a concurrent increase in velocity would increase the shear. As none of these hypothesized changes were observed, it is not surprising that horizontal shear did not change from pre-test to post-test.

Gait velocity did not change for any of the three groups in this investigation. It can be hypothesized that a change in gait velocity may be dependent on the multiple interactions of several factors and resistant to change of one specific factor, such as an improvement in sensory integration. Gait velocity may be dependent on factors such as muscular strength and endurance, as well as sensory integration (Craik, 1989). Although improvements in sensory functioning are undoubtedly important for effective and safe ambulation in older adults, changes in these systems may be masked by poor lower extremity strength. It can be hypothesized that by having the participants walk maximally, as fast as was comfortable, the study may have yielded better results due to an increased use of lower extremity strength. An increase in gait speed would have caused the participants to generate greater force through the lower extremities. Tinetti and colleagues demonstrated the effect of a multi-factorial intervention on improving balance and decreasing the risk of falling in a group of older adults (Tinetti, Baker, McAvay, Claus, Garrett, Gottschalk, Koch, Trainor, & Horwitz, 1994). Muscular strength and changes in behavior and medication usage were examined to determine whether these factors would result in a change in falling rates in a group of older adults. Although the researchers in this investigation did not target stepping strategies as a variable they attempted to improve, the results do suggest that general improvements in balance, whether static or dynamic, are dependent on the improvement of multiple factors. Improvements in lower extremity strength allow for an older adult to better stabilize himself or herself, whether it is under static or dynamic conditions. An improvement in flexibility, as well, allows for a better, and more efficient, adjustment of the body during conditions of instability (Spirduso, 1995).

Although the results of this investigation revealed no significant differences among groups, data about the performance of obstacle avoidance strategies in older adults was of interest. The older adults adopted a more conservative stepping strategy when faced with the obstacle in their path as measured by the toe and heel clearance measures, which is consistent with other studies examining stepping in older adults (Chen et al., 1991; Judge, Davis, & Ounpuu,1996). Toe and heel clearance measures were consistent with other studies examining stepping strategies in older adults (Chen et al., 1991). In previous investigations, older participants had significantly greater measures of toe and heel clearance, when compared to participants in this investigation, in an effort to guarantee a clearance of the obstacle in their path. Most of the participants would focus on the obstacle during the entire approach, even when instructed to look forward until they were about to step over the obstacle.

The results of this experimental investigation make interpretation of stepping strategies in a laboratory setting difficult to relate to stepping in the actual environment. It is not often that an older adult has the ability to determine where they will begin walking when faced with stepping over an obstacle, although they do have the ability to adjust their speed and steps during walking. Stepping up onto a curb is an example of an instance when an individual does have an opportunity to change their gait as they approach the curb. This activity, however, does not require the individual to step over an obstacle, as they are stepping onto a surface that is higher than the surface before the curb. The older adult must make a rapid adjustment in their gait prior to any stepping action over an obstacle.

VARIABILITY IN THE RESULTS

One of the most interesting findings of this study was the degree of variability in the performance of stepping among subjects in the five specific dependent variables. Measures of toe clearance, heel clearance, and horizontal shear showed the greatest variability, while crossing speed and gait velocity showed lesser variability. Increased variability for measures of toe clearance was consistent with previous investigations (1.12 cm +/— .50 cm; Winter, 1991). As variability was expected to be an issue with this investigation due to the inherent individual differences seen in older adults (Spirduso, 1995), measures of variability for toe clearance, heel clearance, and crossing speed were obtained for a group of young adults to determine if variability was an age-related factor, or if stepping over an obstacle is simply a highly variable task. The younger adults demonstrated large variability in measures of toe clearance and heel clearance. These results were consistent with data from a previous investigation by Chen and colleagues (1991). When examining gait patterns in healthy young and older adults, these researchers examined the variability between these groups and found no significant differences. Improvements in the variability of obstacle avoidance measures may occur by simply improving the consistency of the stride length in older adults through the use of a metronome, thus decreasing the variability of the stepping action. Thus, these investigations appear to substantiate the hypothesis that stepping, as well as stride length, is a highly variable task across all age groups.

The large standard deviations (Table 3) obtained during this investigation for between-subject measures may be due to several factors, including where the obstacle is placed in the gait cycle. It was observed during data collection that the initial placement of the subject before the walking trial highly influenced their stepping during the subsequent trial. If the participant began walking further back from the obstacle, they often would find themselves further away from the obstacle during the crossing step. If a participant crossed the obstacle with their supporting foot further away from the leading edge of the obstacle, heel clearance was often closer to the obstacle than if they had crossed the obstacle with their supporting foot closer to the leading edge. Toe clearance was also affected by the starting position. If the participant crossed the obstacle with their supporting foot closer to the leading edge of the obstacle, they appeared to take a more conservative step.

The data also suggest, however, that the variability in the speed at which the older adult crosses the obstacle is not as great as that seen in measures of toe and heel clearance (Table 3). It can be suggested that speed of crossing is not influenced by these previously discussed factors, such as initial starting position of the person prior to walking or foot placement during the initial stepping movement. Changes in postural control characteristics, although affecting the toe and heel clearance measures, has limited influence on the speed at which an older adult crosses an obstacle. It can be hypothesized that improvements in lower extremity strength may improve the ability of an older adult to step over an obstacle due to changes in both the leading and trailing limbs. Improvements in the strength of musculature, such as the hip flexors, would allow an older adult to swing the leg more quickly and efficiently over the obstacle, or raise the leg higher, thus getting the limb across in a shorter period of time in an effort to avoid contact. Additionally, improvements in strength in the trailing limb, which is also the supporting limb during the stepping action, would provide a more stable support for the step and allow a more efficient crossing. As the focus of the intervention was to improve sensory functioning, and not improve muscular strength, a sensory intervention that also stresses lower extremity strength may be more productive and allow for greater improvements in crossing speed.

Additionally, postural control may play a role in the variability of the stepping action. When an older adult begins the movement of the leading foot over the obstacle, they are standing in single support by the trailing leg. The trailing leg is the sole support during the crossing. An inability to remain in a balanced position during this movement may result in sudden and unexpected positional changes in the leading foot/ leg. A loss of balance during the swing phase may force the older adult to place their foot down quickly. This is not a surprising finding, as 80% of the stride is in single support (Winter, 1991), thus accounting for an inherently less unstable condition during the stepping action. By having to place the leading foot down to re-stabilize the body, distances from the obstacle may be variable depending on where in the swing phase the loss of balance occurred. This occurrence was observed for several participants during data collection. Several individuals appeared to become unsteady during the crossing of the obstacle and would rapidly place their leading foot on the ground in an effort to regain double support. This demonstrated change may impact both the toe clearance measures, as the foot may travel different paths over the board under unstable balancing conditions, as well as the completed heel clearance at the conclusion of the swing phase. It does appear, however, that changes in postural control during the swing phase of the stepping action does not impact crossing speed, as the results suggest limited variability in this measure. Additionally, the natural posture of the participant may have also impacted their ability to perform the task effectively. Individuals with inefficient posture may have had increased difficulty performing the stepping action due to a forward displacement of the center of mass, which would increase instability due to the COM positioning near the natural stability limits of the individual.

LIMITATIONS

Five days of experimental sensory training was not sufficient to effect a change in the multiple sensory systems that are being targeted. Hu and Woollacott (1994) were successful in improving static measures of balance in a group of older adults using a sensory training protocol. Their study, however, consisted of ten days of sensory training, which appears to be an effective amount of time for effecting sensory change. Five days was chosen due to literature that suggested this amount of time is sufficient for improving sensory capabilities, as well as being a period of time for which older adults were willing to commit to daily practice (Brandt, T., Buchele, W., & Krafczyk, S., 1986).

Another problem encountered during the study was the inability of several individuals (n = 3) within the experimental group to complete the entire sensory training protocol. These participants were unable to perform all trials of the foam walking trials of the experimental treatment. This was often due to the participants' fear of losing their balance during the foam walking, as well as feeling uncomfortable walking on such an "unusual" surface. These participants reported that walking on the foam surface was "very difficult" and required more strength than walking over a flat, firm surface. When the sensory alterations were added (eyes closed, head tilted), these participants were unable to complete all trials. Additionally, several of the participants reported unexpected soreness and discomfort in their lower extremities following the first several days of the intervention. This resulted in their inability or unwillingness to attempt several of the tasks. This was unexpected, as the nature of the tasks was designed to not be strenuous.

Another limitation in this investigation was the sample size for each group. There may have been a training effect from the performance of the sensory retraining protocol in these individuals, but may have not been observed due to the limited power of the sample size (Beta = .692).

Additionally, the group of participants may not have been representative of the older adult population. These individuals were highly motivated and generally healthy older individuals who had decided to voluntarily participate in this investigation. Examining the effect of this type of protocol on older adults that are significantly less healthy, thus allowing for greater levels of improvement, may increase the likelihood of improving gait and stepping simply due to a decreased function in these older adults, allowing for more significant, and observable, changes in performance. Modifications in research design, however, would likely be necessary for utilization of this type of protocol with less healthy older individuals, due to the observed difficulty of completing all trials in this current healthy group of older adults. These modifications may include decreasing the number of overall trials, alterations in only one sensory system during the intervention, and possibly most important, decreasing the thickness of the foam walking surface to a more comfortable, yet challenging, thickness when attempting to alter proprioceptive inputs.

CONCLUSIONS

Effective and safe walking, and more specifically, stepping over an obstacle, is a movement that is highly dependent on the successful interaction of multiple factors. These factors include muscular strength, flexibility, sensory integration, motivation, and self-confidence. As this exploratory investigation revealed that changes in sensory integration were resistant to five days of sensory training activities, the results support the conclusion that changes in movement capabilities in older adults is dependent on the successful integration of multiple factors, and that effecting a change in movement behavior, such as stepping, is dependent on the improvement of various factors. An improvement in stepping and obstacle crossing strategy is most likely due to visual, vestibular, and proprioceptive capabilities, as well as improvements in muscular strength and endurance and an older adult's perceived ability to perform the task. Although the results of this investigation were disappointing, the results suggest that five days of sensory training may not be an effective amount of time to elicit changes in gross motor tasks, such as obstacle crossing, in a clinical setting. Additionally, multisensory training tasks used to improve motor functioning (Hu & Woollacott,1994) may be too difficult for older adults to complete at a level that would be effective for altering sensory capabilities necessary for dynamic gross motor tasks. Based on the results of this exploratory investigation, future investigations should examine the effect of combining sensory training protocols with strength training programs to improve measures of functional lower extremity strength. Programs to improve multiple factors may be beneficial in improving gait in older adults and ultimately improve older adults' ability to remain independent and functional and improve their quality of life in their later years.

NOTE

1. Innovative Sports Training, Inc., N. Broadway, Suite 119, Chicago, IL USA 60613

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