ORIGINAL ARTICLE

Tactile Intervention as a Novel Technique in Improving Body Stability in Healthy Elderly and Elderly with Diabetes

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Abstract

Background: Body sway increases in the elderly because of normal aging and high incidence of disease such as diabetes. Prevalence of sway is greater in the elderly with diabetes because of damage to the central and peripheral nervous systems. Increase in body sway is associated with an elevated risk of falling. Falling is one of the major causes of morbidity and mortality in the elderly. The purpose of this study was to develop a new technique to improve body stability and decrease body sway in the elderly people with or without diabetes.

Subjects and Methods: Twenty-two subjects—12 elderly (mean age, 75.5 ± 7.3 years) and 10 age-matched elderly with diabetes (mean age, 72.5 ± 5.3 years)—were recruited for this study. Subjects received tactile feedback as a tingling sensation resulting from electrical stimulation triggered by body sway.

Results: The results showed a significant reduction in body sway in the elderly while standing on foam with eyes open (1.0 ± 0.31 vs. 1.9 ± 0.8 ; $P=0.006$) and eyes closed (1.8 ± 0.7 vs. 3.3 ± 1.5 ; $P=0.001$). In the group with diabetes, there was a significant reduction in body sway while standing on foam with eyes closed (1.4 ± 0.5 vs. 2.3 ± 0.8 ; $P=0.045$) but not with eyes open.

Conclusions: In this small study, this technique offers a new tool for training people with diabetes and elderly people to improve body stability and balance.

Introduction

BALANCE IS THE STEADINESS of the human body and the ability to maintain posture during static or dynamic stressors.¹ It is a complex mechanism involving integration and coordination among sensory, motor, and biomechanical activities to prevent falls and improve static and dynamic performance. Loss in coordination among those activities causes faulty body movements, which are presented as sway, loss of balance, or a possible fall.^{1,2}

The elderly population is growing quickly in the United States. According to the U.S. Department of Health and Human Services, the increase in the elderly population in the United States in the year 2010 compared with 2000 was about 24.6%, and the elderly population is expected to double in 2030 in comparison with the year 2000 because of the addition of the “Baby Boomers.” According to the U.S. Department of Health and Human Services, the prevalence of

diabetes in people 65 years of age or older was 26.9% in 2010, affecting 10.9 million persons.³ According to the World Health Organization, there were 171 million individuals affected with diabetes in 2000. However, the projected increase in individuals affected with diabetes by 2030 will be 366 million people.⁴

Aging involves many physiological changes affecting postural control, body stability, coordination, gait, and body balance.^{2,5} This is evidenced by the increase in fall incidence among the elderly.^{5–7} Vestibular, visual, and somatosensory dysfunction and sensorimotor delay occur in the elderly because of the normal aging process and of the high incidence of diseases that affect stability of the human body.

Vestibular activity is reduced in the elderly because of an age-related reduction in the sensitivity and number of hair cells and nerves fibers in the vestibular system. This affects postural control significantly and possibly results in dizziness.^{8,9} Decrease in the sensitivity to low-frequency spatial

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motion in vision due to age affects balance as well. Neuropathy decreases the sensitivity of cutaneous, vibration, and/or proprioception senses, causing balance defects due to reduced somatosensory input.¹⁰ The incidence of peripheral neuropathy is around 20% in the elderly.¹¹ Wolfson et al.¹² tested the sway in normal older adults versus young subjects using the EquiTest[®] dynamic posturography platform (NeuroCom[®] International, Clackamas, OR); they reported that the sway was greater in the elderly than in the young in five out of six sensory test conditions. This finding indicates that there are deficits in balance and postural control due to aging that cause the elderly to have greater sway and a higher risk of fall than younger individuals.

Diabetes that is not controlled can affect postural control and balance through causing defects in the central nervous system, peripheral nervous system, vision, vestibular system, and/or musculoskeletal system. Diabetes affects vision by causing diabetic retinopathies, which is the leading cause of blindness in older adults.¹⁰ Also, diabetes can cause cataract or glaucoma, which affects visual clarity and acuity and the visual field.¹⁰ Visual impairment impacts body balance because the vision is a strong contributor to body balance and predominates the somatosensory and vestibular input.¹³ From 60% to 70% of patients with diabetes suffer from peripheral neuropathies. Peripheral neuropathy affects sensory and/or motor function. This may lead to a loss of tactile, vibration, or proprioception sensation, muscle weakness or atrophy, or diminished vasomotor control.¹⁰ Loss of sensation and/or muscle weakness in peripheral neuropathy affects human balance and postural control and results in a higher risk of falls.^{2,14}

Falling is one of the major causes of morbidity and mortality in the older adult population.¹⁵ According to the Centers for Disease Control and Prevention, one out of three elderly people had at least one fall.¹⁶ Fernie et al.¹⁷ reported that 42% of 205 old subjects in their study had at least one fall within a year. Also, according to the Centers for Disease Control and Prevention, there were 2.3 million falls among the elderly in 2010, and 662,000 were treated in emergency room or hospitalized.¹⁶ The medical cost to treat fall-related injuries among the elderly in 2010 was around 30 billion dollars.¹⁶

On average, 30% of falls in the elderly lead to serious physical injuries, which increase the mortality rate.¹⁵ There were 10,300 fatal falls and 2.6 million nonfatal falls treated medically in 2001. The medical cost to deal with fatal falls was 200 million dollars and 19 billion dollars to treat fall-related injuries.¹⁸ Traumatic brain injury is a serious injury that leads to death in 47% of elderly people with a fatal fall.^{15,16,19} The mortality rate is high among the elderly because of falls (21,700 older adults died because of fall injuries in 2010).¹⁶

Based on previous literature, older people with or without diabetes are at high risk of balance disorders, which are indicated by increased body sway, reduced postural control, or increased incidence of falls. Falls can lead to fatal or nonfatal injuries. Medical costs to deal with injuries resulting from falls are very high and place a burden on the country's economy. Therefore, we should find ways to improve body balance and postural stability to reduce body sway to decrease the incidence of falls among older adults and people with diabetes.

Menz et al.²⁰ tested the instant effect of passive tactile stimulation on body sway in young individuals, elderly

people without peripheral neuropathy, and elderly people with diabetic peripheral neuropathy. They applied Velcro[®] (Velcro USA, Manchester, NH) on the ankle, calf, or knee. They found significant reduction in sway in all groups. At the same time, the sway reduction was correlated directly with the distance between the Velcro and ankle. This means that if you apply the Velcro closer to the knee, body sway will be reduced more. Other studies showed that the application of additional tactile input using a light touch of the fingertip reduces the fluctuation of the center of pressure in bipedal stance or tandem Romberg stance in subjects with intact or impaired somatosensory input.^{21–23}

The current regimen in balance training requires about 1 h of training for two or three times per week for 6–8 weeks as indicated by Song et al.²⁴ This kind of training can be exhausting for older adults because of fitness limitations or general health issues that may be a boundary for old adults to participate in such training. The purpose of this study was to examine the effect of tactile feedback on body sway in the elderly compared with age-matched subjects with diabetes. To our knowledge, tactile feedback is a novel intervention because there have not been any studies done in this regard in the literature using the same approach or feedback system that is tested here.

Subjects and Methods

Twenty-two subjects participated in this study. They were recruited using flyers and phone calls from physical therapy centers, senior homes, sport centers, or Loma Linda University. The subjects, 65–90 years of age, were divided into two groups: an elderly group and an elderly group with diabetes. There were 10 subjects in the elderly group with diabetes and 12 subjects in the elderly group. Subjects were excluded if they had cognitive disorders, neurological disorders, or alcohol/substance abuse, took medications that affect body balance, had vestibular pathology, were unable to stand for 10 min continuously, or had been enrolled in balance training interfering with the provided intervention within the last month. All subjects were screened with a 10-g monofilament test for neuropathy, and only one subject failed the test. All protocols and procedures were approved by the Institutional Review Board of Loma Linda University, and all subjects signed a statement of informed consent. The demographics of the subjects are shown in Table 1. There were no significant differences in age, height, or weight between the two groups.

Technique for measuring body sway

The displacement of the subjects' center of gravity was measured using a balance platform 1 m² in size and 10 cm in

TABLE 1. DEMOGRAPHIC CHARACTERISTICS BY STUDY GROUP (N=22)

	Elderly (n = 12)	Elderly with diabetes (n = 10)	P value
Age (years)	74.3 ± 7.3	72.5 ± 5.3	0.518
Height (cm)	163.0 ± 6.6	169.3 ± 9.2	0.075
Weight (kg)	75.6 ± 14.2	74.9 ± 29.2	0.942

Data are mean ± SD values.

height. Four stainless steel bars with 16 strain gauges were mounted at the four corners under the platform's surface (TML strain gauge FLA-6, 350-17; Tokyo Sokki Kenyajo Co., Ltd., Tokyo, Japan). The output of the four Wheatstone strain gauge bridges was amplified with a BioPac (Goleta, CA) 100 C low-level biopotential amplifier and recorded on a BioPac Mp-150 system through a 24-bit A/D converter. The sampling rate was 2,000 samples per second.²⁵

Sway was presented as a line on a screen detecting the magnitude and angular displacement of the body. The magnitudes of the x - and y -coordinates of the subject's center of gravity were used to calculate the displacement of the center of mass of exerted body load on the platform. Mean and SD were obtained by finding the average of the sway magnitude of y and x over an interval of 6 s.

Design of tactile feedback intervention

The magnitude of body sway measured by the platform was presented on a screen through the BioPac system and using Acknowledge version 4.2 software as a white line. A photocell, sensitive to the light emitted by the sway line, was attached to the screen. A relay station was connected between the stimulator (STIMSOC; BioPac) and stimulator output to control the trigger for stimulation. Stimulation consisted of a square wave of 200 ms in duration at a frequency of 40 Hz. The amplitude depended on the threshold of tactile sensation of the subject and ranged between 5 and 20 mA. Stimulation was triggered depending on the input from the photocell that was attached to the screen. If the sway exceeds 50% of average body sway for the subject, the photocell would convey a signal to the relay station ordering it to close the circuit and trigger the electrical stimulation through the stimulator output. Two electrodes were attached to the lateral aspect of the subject's right lower leg. The subject would feel the electrical stimulation as a tingling sensation cuing him or her to stop sway and hold steady. This mechanism resulted in tactile feedback triggered by the body sway to improve body stability among the elderly by decreasing body sway (Fig. 1).

Balance tasks

Four balance tasks, each lasting for 10 s, were included in this study. Two surface compliances (firm surface and foam) were used. The trial was conducted in a darkened room to increase the challenge of the tasks. The four balance tasks were as follows: (1) standing on a firm surface (platform) with feet apart and eyes open; (2) standing on a firm surface (platform) with feet apart and eyes closed; (3) standing on a compliant surface (foam) with feet apart and eyes open; and (4) standing on a compliant surface (foam) with feet apart and eyes closed.

Procedures

The subject was asked to stand quietly on the platform with eyes open for 10 s. Then, the subject was asked to stand quietly on the platform with eyes closed for 10 s followed by 1 min of rest. Following the 1 min of rest, the same procedures were repeated again while the subject stood on foam.

After finishing the baseline measurements, the subject received the tactile feedback intervention. Two electrodes were placed on the proximal third of the lateral aspect of the right lower leg to provide the subject with tactile feedback. The subject was asked to stand quietly on the platform for 4 min divided into two sessions, 2 min each, with 2 min of rest between them. The subject was asked to keep the eyes open in the first training session and then close the eyes in the second training session. Following that, the subject was given a 2-min rest. Then, the subject was asked to stand quietly on foam for 2 min with his or her eyes open. If the subject swayed during the training session, he or she would feel tingling on the lower leg to remind him or her to stop swaying. Postintervention measurements were conducted following 2 min of rest after the second session of intervention and 5 min of rest following the postintervention measures. Post-intervention measures were the same as the measures prior to the intervention.

FIG. 1. Tactile feedback system.

FIG. 2. Mean body sway (in kg) while standing on foam with eyes open in the elderly group pre- and postintervention. * $P=0.006$.

Data analysis

The general characteristics of the subjects were summarized using means and SDs for quantitative variables and frequencies and relative frequencies for categorical variables. A 2×3 mixed factorial analysis of variance and one-way repeated-measures analysis of variance were used to examine the difference in mean body sway between and within subjects. The level of significance was set at 0.05.

Results

There was no significant difference in mean body sway between the elderly group and the group with diabetes on any of the tasks preintervention, postintervention, or at 7 min postintervention. Body sway decreased significantly in all tasks that involved using foam in the elderly group. The average body sway decreased significantly in the elderly group when standing on foam with feet apart and eyes open postintervention compared with preintervention (1.0 ± 0.31 vs. 1.9 ± 0.8 ; $P=0.006$) (Fig. 2). Sway decreased significantly in the elderly group when standing on foam with feet apart and eyes closed postintervention compared with preintervention (1.8 ± 0.8 vs. 3.3 ± 1.5 ; $P=0.001$) (Fig. 3). There was no significant difference in mean body sway when standing on foam with feet apart and eyes open in the group with diabetes. Body sway decreased significantly in the group with diabetes when standing on the foam with feet apart and eyes closed postintervention compared with preintervention (1.4 ± 0.5 vs. 2.3 ± 0.8 ; $P=0.045$) (Fig. 4). There was no significant difference in mean body sway between immediate postintervention measures and 7-min postintervention measures.

FIG. 3. Mean body sway (in kg) while standing on foam with eyes closed in the elderly group pre- and postintervention. * $P=0.001$.

FIG. 4. Mean body sway (in kg) while standing on foam with eyes closed in the group with diabetes pre- and postintervention. * $P=0.045$.

Discussion

Balance deteriorates with aging because of the normal aging process and the high incidence of disease among the elderly population. Sensory deficits in the lower extremity, visual impairment, and vestibular impairment contribute significantly to poor postural control in the elderly.^{26–30} The case is worse with elderly people with diabetes because the disease can affect the central and peripheral nervous systems, vestibular system, and vision, resulting in poor sensory input and limited central processing of the information received by the brain leading to poor body balance.^{10,31,32} Defects in body balance result in increased body sway, decreased postural stability, and increased incidence of falls.

According to the Centers for Disease Control and Prevention, there were 2.3 million falls among the elderly in 2010, and 662,000 were treated in emergency rooms or hospitalized.¹⁶ The medical cost to treat fall-related injuries among elderly in 2010 was around \$30.0 billion.¹⁶

Falls lead to serious injuries in elderly people and increase their mortality rate.¹⁶ Statistics show that 30% of falls in the elderly result in serious injuries.¹⁵ Medical costs to deal with fall-related injuries in the elderly are very high. The medical cost to deal with fall-related injuries is expected to be 43.8 billion dollars by the year 2020.¹⁵

The results of the current investigation showed significant reductions in body sway in the elderly group while standing on foam with the eyes open or closed. However, the significant reduction in body sway in the elderly group with diabetes was only while standing on the foam with eyes closed but not with eyes open. There was no significant reduction in body sway in the elderly group with diabetes or the elderly group while standing on the platform because it was not challenging enough to increase the body sway and show a difference in body sway postintervention.

Rogers et al.³³ found that the reduction in body sway was more in subjects who swayed the most during normal standing. Therefore, we expect less reduction in body sway in the elderly group or the elderly group with diabetes while standing on the platform because this situation is not challenging enough for subjects' body posture because of the hard surface was used.

Body sway decreased in the elderly group with diabetes because of intervention while standing on foam with eyes closed but not with eyes open. This shows that the group with diabetes relies more on their vision in controlling their body balance than using the vestibular system or somatosensory

system because vision predominated the inputs of both systems in maintaining body balance in normal situations.¹³ This may justify why they did not learn new strategies to control their body sway using tactile stimulation with the eyes open. This is probably an adaptation used by subjects with diabetes to overcome sensory loss and vestibular loss. But, when the subjects were asked to close their eyes, the only way to control their body balance was to rely on the vestibular system and somatosensory inputs. Although the vestibular system and somatosensory sensory inputs are not strong contributors to body balance in people with diabetes compared with vision, the subjects with diabetes relied on them to learn how to hold their body balance because the eyes were closed.

Menz et al.²⁰ found that body sway decreased in the elderly with diabetic peripheral neuropathy and the elderly without peripheral neuropathy while applying a tactile stimulation on the lower leg using Velcro attached to an elastic band. Velcro was applied at three levels of the lower leg: at the ankle, mid-calf, and the knee. The reduction in body sway was more in applying Velcro at the knee, then mid-calf, and then the ankle.²⁰ This showed, even in the elderly without peripheral neuropathy, that tactile input was better as the application of stimulation was more cephalic. This can be attributed to mild damage in nerves in the elderly as we go more toward feet, or the fastest conduction of the nerve as we go toward the knee, due to the reduction in distance between the nerve ending and somatosensory area. This fact explains why we applied the tactile stimulus in the proximal third of the lower leg in our study.

Tactile input through the fingertip helped in reducing body sway and minimizes the fluctuation in the center of pressure in the elderly with or without impaired proprioceptive input in the lower limbs.^{21–23} Light touch improves body stability in the elderly with impaired proprioceptive input because it provides tactile input, which helps in compensating for poor proprioception. In our study, the elderly without proprioceptive impairment improved as well. This finding suggests that the elderly had mild impairment in peripheral sensory input but did not reach the threshold to be detected through the clinical examination tools as a peripheral neuropathy. This supports the use of a cane in the elderly because it will provide tactile input and mechanical support to improve body stability and reduce the risk of a falling.

The effect of Velcro application and fingertip light touch in the above-mentioned studies was studied instantly. There was no measurement of body sway postintervention to find the effect of intervention. In the current study, we studied the effect of tactile feedback following the training session to find the effect postintervention.

In a previous study, the effect of passive tactile application on the shoulder versus the lower leg on postural stability was studied in healthy young adults and people with diabetes with varying degrees of peripheral neuropathy. Results of this study showed more reduction in body sway with a stimulus applied to the shoulder than the lower leg, and the stimulus was more effective with eyes closed or standing on the foam.³³ This study supports the results of our current study because the reduction in body sway was more while standing on foam than on the platform. At the same time, body sway in the group with diabetes decreased more with the eyes-closed situation than the eyes-open situation. However, this

technique still worked well in the people with diabetes to train balance.

Limitations of this study were the intensity of treatment, the carryover measures, and a small sample size. Future studies are recommended to study the effect of multiple sessions instead of one training session and to study the carryover effect of intervention using a bigger sample size to be more representative of the studied population. Factors that may alter outcomes included duration of diabetes, hemoglobin A1c level, age, and gender. All of these factors need to be investigated further. To our knowledge, this is the first study that examined the effect of this novel intervention on body stability among elderly subjects.

Conclusions

In this small study, this technique offers a new tool for training people with diabetes and elderly people to improve body stability and balance.

Author Disclosure Statement

No competing financial interests exist.

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