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ORIGINAL ARTICLE

Effect of somatosensory and neurofeedback training on balance in older healthy adults: a preliminary investigation

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Abstract The aim of this study was to assess the effectiveness of balance training with somatosensory and neurofeedback training on dynamic and static balance in healthy, elderly adults. The sample group consisted of 45 healthy adults randomly assigned to one of the three test groups: somatosensory, neurofeedback, and a control. Individualization of the balance program started with pre-tests for static and dynamic balances. Each group had 15- and 30-min training sessions. All groups were tested for static (postural stability) and dynamic balances (Berg Balance Scale) in acquisition and transfer tests (fall risk of stability and timed up and go). Improvements in static and dynamic balances were assessed by somatosensory and neurofeedback groups and then compared with the control group. Results indicated significant improvements in static and dynamic balances in both test groups in the acquisition test. Results revealed a significant improvement in the transfer test in the neurofeedback and somatosensory groups, in static and dynamic conditions, respectively. The findings suggest that these methods of balance training had a significant influence on balance. Both the methods are appropriate to prevent falling in adults. Neurofeedback training helped the participants to learn static balance, while somatosensory training was effective on dynamic balance learning. Further research is needed to assess the effects of longer and discontinuous stimulation with somatosensory and neurofeedback training on balance in elderly adults.

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Keywords Static balance · Dynamic balance · Somatosensory training · Neurofeedback training

Introduction

Balance is one of the most important factors of physical readiness referred to as an ability to maintain the body in space [1]. Adequate balance requires complex integration of sensory information regarding the position of the body relative to its surroundings. Balance also requires the brain to generate appropriate motor responses to control body movement [2]. Physical and mental degradation occurs with age, and this makes keeping balance during motionless (static balance) or motion conditions (dynamic balance) difficult for elderly people. This means that falling is a common problem among the elderly, and reports indicate that one in three people aged 65 years and over fall at least once each year [3]. Age demographics show that the aging index has grown over recent years in many societies, and balance is critical for these groups. Much research attention has been directed to studying the factors affecting balance. A significant amount of research has focused on balance improvement and fall prevention through different programs in older adults. Each of these methods has created an impact on the infrastructure of balance to improve performance. In this study, two experiments were conducted to test the effects of somatosensory and neurofeedback training on balance in elderly adults.

Somatosensory training

To date, the primary causal factors related to pathology of imbalance have yet to be determined, but several risk factors have been proposed. These have been identified as physical health and cognition, physical frailty, and other age-related changes in physiological function, such as orthostatic hypotension and perceptual processing [2, 4]. Specifically, balance control depends on a complex process that involves a coordinated set of sensorimotor interactions that continually integrate information from the relevant senses, particularly the vestibular, proprioceptive, auditory, and visual modalities [5]. Studies suggest that any increase in sensory information may lead to improvement of balance in the elderly. Stimulation of the soles of the feet is one kind of intervention that could improve proprioception and the somatosensory system [6]. Several studies have demonstrated the relationship between plantar stimulation and control of balance. Other studies have revealed that tactile sensation could be beneficial for the prevention of falling in adults [7]. For example, it was shown that footwear interventions, such as foot orthoses and insoles, could affect both static and dynamic functions. Suppressing or stimulating the plantar afferents are both relevant methods to describe the role of tactile messages in postural control. There are other approaches that consist of changing the characteristics of the supporting surface [8]. Priplata et al. found that vibrating insoles could affect short-term postural sway variables in younger and older adults [9]. Palluel et al. conducted a test with sandals equipped with spike insoles for 45 min that improved balance, at least temporarily [8]. Hatton et al. demonstrated that standing on a patterned surface could increase postural stability and improve performance [6].

In general, studies support this theory that somatosensory interventions improve sensorimotor activity. In addition, this may be due to a manifestation of plasticity in the somatosensory cortex. Numerous evidences indicate that variability in the protocols of stimulation, such as two vs. multiple stimulation sites, and parameters, such as duration, frequency, and amplitude, could provide this difference of effects. However, stimulation protocols have not been comprehensively compared yet, and recognizing suitable parameters for somatosensory stimulation interventions is substantially important [10]. For this purpose, one of the aims of this research is to determine the effect of walking on the patterned surface (as a somatosensory intervention) in older adults on static and dynamic balances. It could be a feasible application treatment option for patients enduring sensory loss, abnormal plasticity, or certain forms of motor impairment, especially in the elderly.

Neurofeedback training

Neurofeedback is a training method in which information about change in neural activity is provided to the participant to facilitate learned self-regulation of neural activity to present changes in brain function, cognition, or behavior. It can be used to address a broad range of problems to effective interventions for individuals [11]. There is some evidence to suggest that neurofeedback training (NFT) could enhance balance. During NFT, subjects can learn to selectively control their brain waves to improve motor function. These evidences indicate that NFT relies on neuroplasticity mechanisms. These mechanisms are puissant for inducing short-term and long-term changes in brain activity, such as those reflected in EEG oscillations or hardy response [11]. During these functional changes, gray-matter masses are a criterion of the potential of the brain to undergo neuroplasticity situations [12]. Larger gray-matter masses have been dependent on learning performance in various contexts [13]. Therefore, it is expected that gray- and white-matter features of the brain may indicate the outcome of NFT-training programs. With the further neural network communications during NFT, it seems that static and dynamic balances (as a complex motor function) may improve. For example, Hammond has reported successful NFT treatment (increase beta wave and decrease theta wave) of four patients with different balance problems [14]. Basta et al. stated that these systems are possibly promising in the therapy of chronic peripheral vestibular disorders [15]. Rossi-Izquierdo et al. confirmed that vibrotactile NFT reduced numbers of falls [16]. Azarpaikan et al. demonstrated that NFT can improve static and dynamic balances in patients with Parkinson's disease [17]. Accordingly, the other aim of this research is to determine the effect of NFT (increase SMA wave and decrease theta wave) in the occipital lobes on static and dynamic balances in the elderly.

In general, despite claims of the effectiveness of different methods on static and dynamic balances, these methods have not been compared in terms of superiority. This report describes an experiment to determine differences between somatosensory and neurofeedback trainings on balance improvement in older healthy adults. Since the usefulness of a method depends on its transfer to different situations, to evaluate transfer of learning of each method, two different static and dynamic balance tests were used.

Therefore, the research questions from which our hypotheses were developed include the following:

a. Do somatosensory and neurofeedback training differentially affect acquisition of static and dynamic balances?
b. Do somatosensory and neurofeedback training differentially affect transfer of the ability of static and dynamic balances?

Methods

Participants

Forty-five healthy adults (*M*, age = 67.66 years, SD = 3.1 years) participated in this experiment. Participants had no balance training prior to the start of the study. They completed the General Health Questionnaire (GHQ-28). The Cronbach alpha coefficient for the GHQ is a range of 0.82–0.86 and cut-off score of 9 or greater was used [18]. They also completed the Neurobehavioral Cognitive Status Examination (NCSE). Cut-off score of 11 or greater was used to determine whether the participant was experiencing significant symptomatology of neuro-cognitive disorders [19]. Each patient also provided written informed satisfaction approved by the Institutional Review Board for ethical human subject research. Ethical approval was granted by the local ethics committee. Participants were randomly assigned to one of the three experimental groups ($n=15$): somatosensory, neurofeedback, and a control group. Two participants (one in the NFT group and one in the control group) failed to return for the delayed transfer tests.

Instrumentation

The Biodex Balance System (SD) consisted of the postural stability test in acquisition state (as pre-test–post-test) and fall risk of stability test in the transfer state (both in level 8). These tests were applied to measure static balance. To measure dynamic balance, the Berg Balance Scale (BBS) in acquisition state (as pre-test–post-test) and timed up and go (TUG) test as the transfer state were used. Biograph Infiniti Software system (version 5.0), Flex Comp Infiniti encoder, and TT-USB interface unit were used for the NFT sessions with fiber optic cable and USB cable that provided 24-bit analog-to-digital conversion with an internal sampling rate of 2048 samples/second and 256 sps data rate to the PC (Fig. 1). Patterned surfaces with a length of 5 m were used for the somatosensory sessions. These patterned surfaces were covered with round stiff plastic prominences about 1 cm away from each other (Fig. 2).

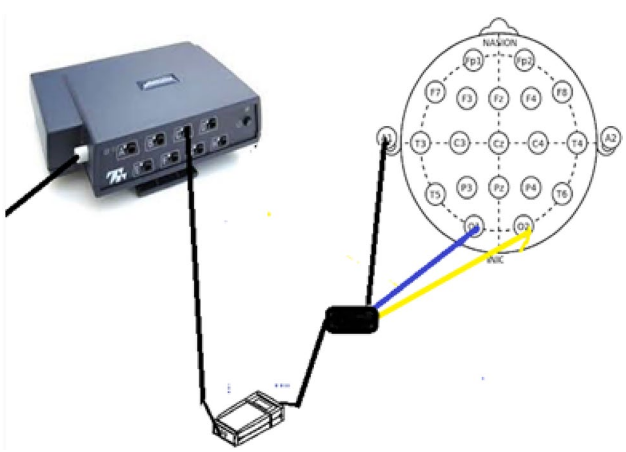


Fig. 1 Illustration of neurofeedback and 10–20 systems

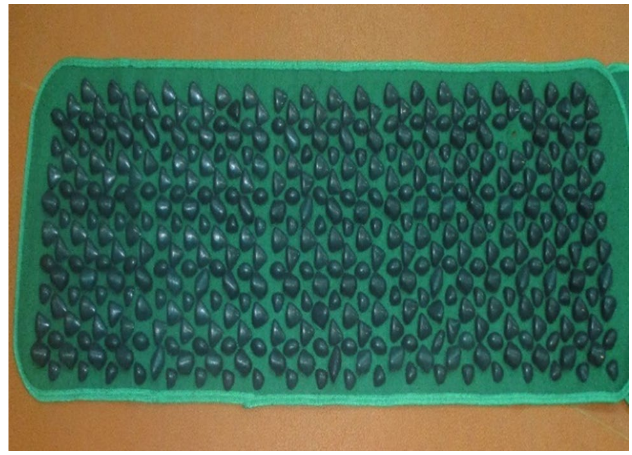


Fig. 2 Illustration of patterned surfaces

Procedures

Tests were done according to the following procedure: during 15 training sessions (5 weeks), participants in both test groups participated in three sessions per week to complete 30 min of their training. The control group only participated in pre–post and transfer tests. They carried out their normal daily tasks during the research period.

Neurofeedback training (NFT)

During 30 min of the neurofeedback training (NFT) session, participants were seated in a comfortable armchair in front of a PC monitor. The international 10–20 system of electrode placement was used to position electrodes on the scalp. Two sensors (active and reference electrodes) were attached to the left and right occipitals (O1 and O2) by bipolar assembly and one (grand electrode) to the subject's left earlobe (Fig. 1). During NFT sessions, participants were asked to play two video (boat and puzzle) games on the computer screen (as the visual feedback) for 30 min. Participants were trained to increase SMA (12–15 Hz) and decrease theta (4–7 Hz) activity. Át the end of each session, EEG baseline was recorded to determine the level of brainwave activity in the CZ (central zero) of the scalp with eyes open and closed.

Neurofeedback performance

To determine the participants' ability to modulate EEG frequencies in the brief time during each training session and to distinguish the performance in the NFT training, the power was averaged per run of training through all 15 sessions [11]. Ninaus et al. explained that variations during sessions are presumably a more useful method in identifying alterations from NFT training than identifying conceivable changes during sessions, which are probably confused by unstable baselines [13]. Furthermore, averaging the data over the sessions and showing an increase of SMR and a decrease of theta power over the runs represent the reliability of participants' ability to moderate the frequency that trained at a time and, meanwhile, degrades the effects of participants' inherent and random oscillations. To evaluate training effects and analyze the time period of SMR/theta power over the training during sessions, linear regression analyses (predictor variable = session; dependent variable = SMR/theta power) were run. This approach permits for a bipartite characterization of the period of training effects on performance. At first, the gradient of the power received an average among all participants aboard the different runs. In addition, this approach gives clearance to the statistical assessment of the average progress in performance compared with the average error perceived during various runs of training. Moreover, it has been indicated that this index is a credible method to recognize the NFT performance of participants [20].

Somatosensory training (SST)

In the somatosensory training (SST), 30 min of each session was divided into three periods as follows: warm up (10 min), walk on a patterned surface (15 min), and cool down (5 min). Individuals performed static and dynamic stretches as well as walking quietly on a smooth surface as a warm-up exercise. During the main part of the practice (15 min), participants were asked to walk on the patterned surface for two consecutive periods and once on the flat floor, alternatively (Fig. 2). Then, they cooled down by slowing down their steps while resting from arm movement.

Testing

Testing for measures of static and dynamic balances was obtained for all participants in pre, post, and transfer tests. Before and after the training sessions, fall risk and timed up and go for measures of static and dynamic balances were administered (acquisition state). Following the acquisition state, after an hour rest period, participants completed the transfer test. The transfer tests were different kinds of static and dynamic balances that included limit of stability and Berg Balance Scale, respectively.

Data analyses

Data analysis was carried out in SPSS 19. First, the independent sample *t* test was run to compare the difference between participants of groups before interventions in terms of demographic features such as age, weight, height, General Health Questionnaire (GHQ-28), and Neurobehavioral Cognitive Status Examination (NCSE). Then, to evaluate static and dynamic tests, a one-way (Group × Time) mixed design analysis of variance (ANOVA), with the group as the between-subjects factor (3 levels), time as the within-subject factor (pre–post and transfer tests), and Tukey HSD for a post-hoc test was used. Mauchly's test of sphericity was used to examine the assumption of sphericity. Since the assumption of sphericity was violated, a Greenhouse–Geisser correction was applied. Confidence interval (CI) of 95% was considered (α: 0.05).

For EEG data analysis and preprocessing, Brain Vision Analyzer software (version 2.01, Brain Products GmbH, Munich, Germany) was used (e.g., muscles and ocular artifacts). The criteria for rejection were: > 50 µV voltage step per sampling point and absolute voltage value was > ± 120 µV. Absolute SMR (12–15 Hz) and theta (40–43 Hz) band power (for EEG data analysis) were elicited by means of complex demodulation [13].

Results

Comparison of the traditional parametric analyses (*t* tests) revealed that pre-intervention, the groups were similar in age, weight, and height (see Table 1). Based on GHQ-28 and NCSE, there were no differences in mental–physical health status among all participants and no cognitive impairment was shown.

In general, means of balance scores were found to have improved after both tested interventions (see Fig. 3). The results of interaction between NFT and SST groups (Table 2) showed that participants could reduce fall risk (2.75, 2.66–1.6, 1.8 respectively). Timed up and go results indicated that participants in NFT and SST groups could significantly decrease the mean of time (15.10, 15.40–11.06, and 9.32, respectively).

Table 1 Characteristics of participants

	Neurofeedback group		Somatosensory group		Control group		*P* value
	Mean	Std	Mean	Std	Mean	Std	
Age (year)	68.04	3.8	68.05	2.9	66.91	3.9	0.61
Weight (kg)	67.40	3.7	65.20	2.5	62.46	2.6	0.28
Height (cm)	161.6	2.9	162.3	2.8	160.7	2.1	0.26
GHQ (28 Score)	5.06	2.0	5.09	1.9	5.04	2.3	0.32
NCSE	7.01	1.5	6.6	2.0	6.9	1.8	0.91

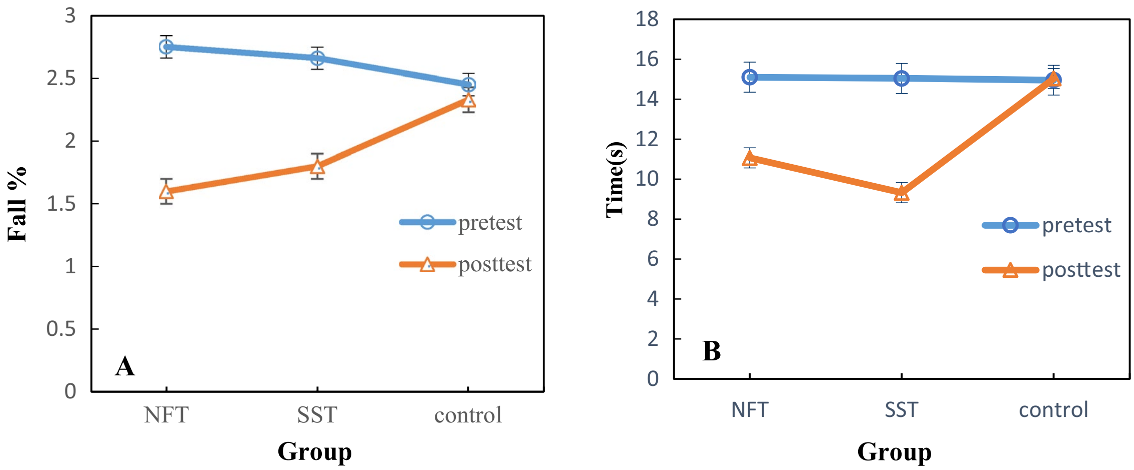


Fig. 3 Mean scores change in NFT, SST, and control groups during acquisition. **a** Fall risk test for static balance, and **b** time up and go for dynamic balance

Table 2 Pre–post comparison and transfer tests regarding group's mean ± Std

Variable group	Testing time			*p* value	
	Pre-test	Post-test	Transfer test	Group	Post-hoc
Fall risk[a]	2.75 ± 1.34	1.6 ± 1.07		0.00	
Fall risk[b]	2.66 ± 1.62	1.8 ± 1.21		0.01	
Fall risk[c]	2.45 ± 1.33	2.33 ± 1.11		0.75	
Limit of stability[a]			50.21 ± 2.01	0.02	0.00
Limit of stability[b]			39.04 ± 3.21		
Limit of stability[c]			24.12 ± 2.14		
Timed up and go[a]	15.10 ± 2	11.06 ± 2.3		0.00	
Timed up and go[b]	15.04 ± 2.5	9.32 ± 2.0		0.00	
Timed up and go[c]	14.95 ± 1.8	15.03 ± 2.12		0.20	
Berg Balance scale[a]			40.13 ± 2.71	0.02	0.00
Berg balance scale[b]			49.03 ± 1.17		
Berg balance scale[c]			27.14 ± 2.50		

[a]Neurofeedback group
[b]Somatosensory group
[c]Control group

In addition, results of transfer tests showed that the interventions might have had a significant different effect on of static and dynamic balance transfer abilities as shown in Fig. 4.

According to Table 2, in limit of stability (as transfer static balance test), Tukey HSD post-hoc showed that the NFT group had significantly better scores (50.21) than those in the SST group (39.04). In terms of the Berg Balance Scale (as transfer dynamic balance test), Tukey HSD post-hoc showed the SST group had significantly better scores (49.03) than the NFT group (40.13).

The result of SMR and theta wave analysis indicates that the linear regression model of the average gradient for SMR wave was significant ($p < 0.05$) and estimated for 69% of variance of SMR power over the training sessions. About 70% of participants showed a positive gradient of the learning curve based on analyzing the time course of SMR power over the training sessions as can be seen in Fig. 5, although the theta waves showed a linear decrease in power over the training sessions. The same regression analysis was conducted for theta wave. The linear regression model of the average gradient for theta wave was significant ($p < 0.05$) and estimated for 73% of variance of theta power over the training sessions. About 80% of participants showed a negative slope of the learning curve as shown in Fig. 6. The results of this regression analysis indicate that NFT group showed a linear increase in SMR power and a linear decrease in theta power over the average of 15 training sessions.

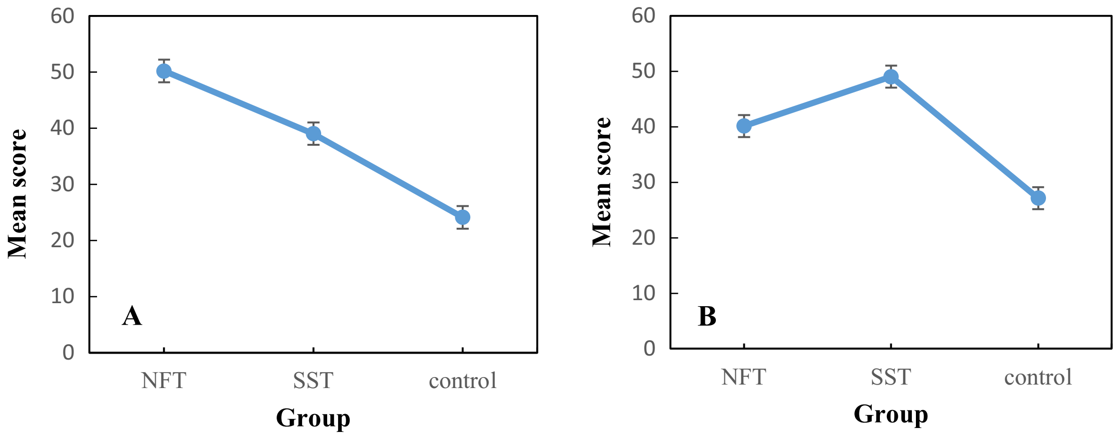


Fig. 4 Mean score of NFT, SST, and control groups for transfer tests. (A) Limit of stability test for static balance, and (B) Berg balance scale for dynamic balance

Fig. 5 Linear regression of SMR learning rates and linear increase in SMR NFT power

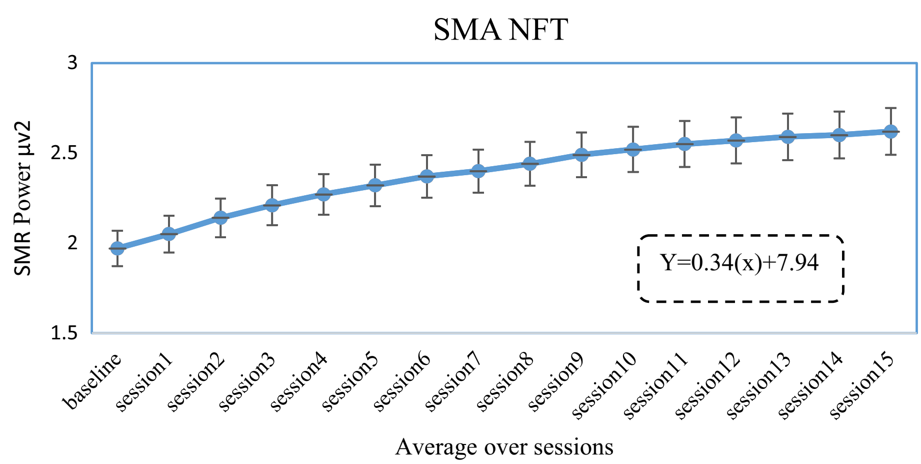
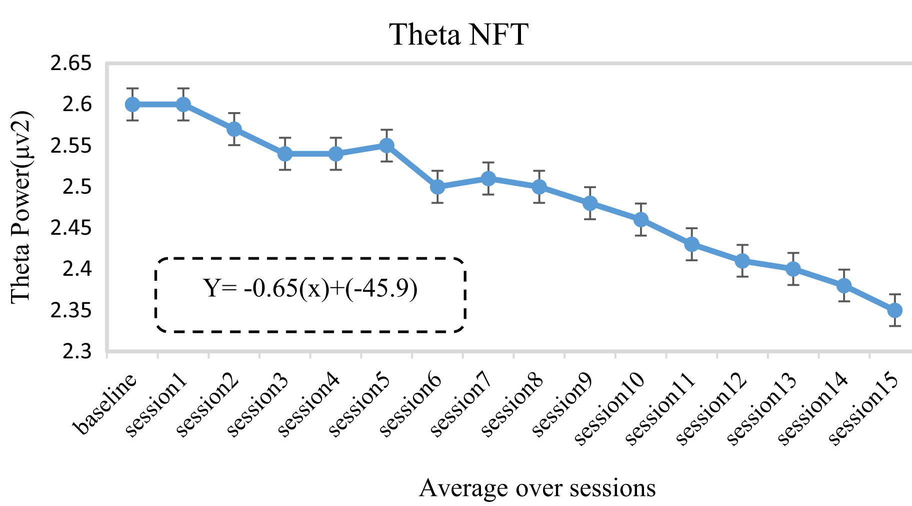


Fig. 6 Linear regression of theta learning rates and linear decrease in theta NFT power



Discussion

The purpose of this preliminary investigation was to examine the effects of somatosensory and neurofeedback training on static and dynamic balances in older healthy adults. The research questions from which our hypotheses were developed were as follows:

1. Do somatosensory and neurofeedback training differentially affect balance in the elderly?
2. Do differing experiences of training conditions impact transfer balance performance in the elderly?

The sample population of this study consisted of older healthy adults; none of whom had cognitive or postural impairment. Therefore, the results of this study cannot be applied to populations with physical or cognitive impairment or those with low-level function. First, results found that both training interventions were successful in improving balance control in older adults in general. According to our prediction, this suggests that both these methods could help elderly people in the prevention of falling and to improve control of postural stability during their daily activities. Second, although the two test groups had better dynamic balance in the acquisition test compared to the control group, the SST group had a significantly higher score than the NFT group. Finally, it was determined that the SST group obtained better scores on the transfer tests of dynamic balance, while the NFT group obtained better scores on the transfer tests of static balance. It is noteworthy that comparison of the two methods (especially these two methods) in two separate part of balances (static and dynamic) has been studied less in the literature before.

Effects of neurofeedback training on balances

Effects of neurofeedback training on balance showed that our hypothesis that neurofeedback training would facilitate better performance and thereby expediting the development of both static and dynamic balances in elderly adults was supported. Previous studies have shown the effect of neurofeedback balance training on patients with balance disability, and therefore [17], our results are consistent with such findings in the related literature. It was observed that participants could promote their control on postural sway in static and dynamic balances. The ability of members of the neurofeedback group to increase the power in SMR and decrease theta frequency bands, respectively, was high and similar to literature standards [21, 22]. Their performance during acquisition and evidence of improved balance score from pre-test to the post-test was not similar to the improvements achieved by members of the control group. Here, there are two alternative explanations: first, it must be conceded that placement of the electrodes plays an important role in providing the information needed to for balance [14]. The points “O1–O2” that were used in this study are close to the brain structures that are involved in balancing, such as the occipital lobe, substantia nigra, basal ganglia, and cerebellum [17]. Halder et al. in their classification suggest that in an SMR brain–computer interface during performance of a participant, the superior fronto-occipital fasciculus contributes to determine the level of individual performance [22]. In this base, the electrode placement (O1–O2) used in this study is compatible by importance of the posterior corona radiata for SMR. A second alternative is that the method employed to elicit a reduction in theta and amplification in SMR is important for maintaining balance. The cortical theta is observed frequently in young children. In older children and adults, it tends to appear during meditative, drowsy, or sleeping states [23]. However, the SMR wave is dominant in the normal waking state of consciousness when attention is directed toward cognitive tasks and the environment. When the individual is alert, attentive, and engaged in physical activity, the SMR wave is present [22]. Accordingly, it would have been possible for the elderly adults in our study to learn that they could reduce their theta (Fig. 6) and increase SMR power (Fig. 5) after the neurofeedback training by engaging in a number of irrelevant cognitive activities to maintain balance. However, in the transfer test, those in the NFT group achieved significantly better scores compared to those in the control group and the SST group. Due to the nature of neurofeedback training group conditions, it seems that participants during static test on the Biodex could clearly regulate their brain waves, even under the new conditions imposed by the transfer test. This demonstrates that the learning process in static balance occurred in individuals in the NFT group. In general, based on our findings and compared to the other studies, it seems that SMR/ theta protocol, which used in this study, is more beneficial for older healthy adults’ static balance.

Effects of somatosensory training on balance

This part of the present study was designed to investigate training based on an intervention using textured surfaces (Fig. 2). It had an impact on somatosensory function in balance control and prevention of falling. Results of these tests suggest that after 15 sessions of SST, static and dynamic balances improved significantly (Table 2) compared to the control group. These findings are consistent with other studies that have reported improved balance in various populations following training programs on a combination of uniaxial or multiaxial unstable surfaces, resistance training incorporating unstable surfaces [24]. Some studies indicate improved postural control in young and elderly people from stimulation of soles of the feet [8, 9]. This provides indirect evidence that the plantar equip relevant tactile information about body position in reference to verticality. During adapting, receptors code the continuous pressure applied to their field [25]. Therefore, it can be suggested that the plantar is a one of the indented surfaces that increases the body's awareness and increases spatial representation of the pressure distribution underfoot [26].

The main principle of using textured surfaces was to enhance sensory input. The efficient postural control relies on the successful integration of multisensory inputs [27]. It is expected that walking on a patterned surface would enhance cutaneous and proprioception sensations as well as postural stability in elderly people. However, results of the current study are not in agreement with those of Wilson et al. and Hatton et al., which reported that textured insoles within standardized footwear did not significantly affect postural sway variables [6, 28]. The research used sandals equipped with spiked insoles for intervention, and it seems that small protrusions on sandals that indent the skin in localized regions cause a relatively small number of adjacent receptors to fire at a high rate [6]. In contrast, this study applied patterned surfaces, which had gently rounded contours that had contact with a larger expanse of skin. This larger expanse induced a lower amplitude firing rate from a higher percentage of receptors. According to the available evidence on the decline in postural sway in both young and older healthy adults by vibrating insoles, this increases the possibility that any effects are dependent on the nature and/or degree of sensory input. It is noteworthy that in the transfer test, people in the SST group achieved better scores than in dynamic balance. These results appear reasonable. SST group training includes separate sections, all of which were designed to be active. These training sessions could be applied to have a significant effect on vestibular and somatosensory systems. Participants learned to control their dynamic balance while practicing a new task.

Comparing the two training groups: the current study suggests that both experimental groups achieved statistically significant improvement in both static and dynamic balances, although textured surfaces did not affect static balance control more than neurofeedback training in healthy participants during the acquisition state. However, under dynamic, as opposed to static testing conditions, texture has been shown to have a significant effect. However, with regard to the transfer test results, the NFT group showed significant improvement in static balance, while the SST group achieved a better score in dynamic balance. Motor learning is a change, which is indicated by the results in retention or transfer tests [29]. According to the transfer test results, it can be determined that learning occurred to control static and dynamic balances in NFT and SST groups, respectively. In general, based on our findings and compared to the other studies, it seems that larger expands inducing stimulation of larger areas and multiple receptors are more beneficial for older healthy adults' dynamic balance.

Conclusion

The present study aimed to investigate possible effects of the NFT and SST programs focusing on the improvement of static and dynamic balances in older healthy adults. Based on the findings of the present study, it can be suggested that the elderly can benefit from both the tested methods to improve their physical balance. However, participants in this study were highly functional with no known postural or cognitive impairment. It is recommended that future studies investigate the effectiveness of reactive response training on performance of daily tasks, trip and fall prevention, and in populations with cognitive and/or postural impairment. In addition, these results should be compared with other balance training methods.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval Ethical approval was granted by the local ethics committee.

Informed consent Each patient also provided written informed satisfaction approved by the Institutional Review Board for ethical human subject research.

References

1. Aartolahti E, Tolppanen AM, Lönnroos E et al (2015) Health condition and physical function as predictors of adherence in long-term strength and balance training among community-dwelling older adults. Arch Gerontol Geriatr 61:452–457
2. Sturnieks DL, St George R, Lord SR (2008) Balance disorders in the elderly. Clin Neurophysiol 38:467–478
3. Paquette MR, Li Y, Hoekstra J, Bravo J (2015) An 8-week reactive balance training program in older healthy adults: a preliminary investigation. J Sport Health Science 4:263–269
4. Graham DF, Carty CP, Lloyd DG et al (2015) Biomechanical predictors of maximal balance recovery performance amongst community-dwelling older adults. Exp Gerontol 66:39–46
5. Chang NY, Uchanski RM, Hullar TE (2012) Temporal Integration of Auditory and Vestibular Stimuli. Laryngoscope 122:1379–1384
6. Hatton AL, Dixon J, Martin D et al (2009) The effect of textured surfaces on postural stability and lower limb muscle activity. J Electromyogr Kinesiol 19:957–964

7. Perry SD (2006) Evaluation of age-related plantar-surface insensitivity and onset age of advanced insensitivity in older adults using vibratory and touch sensation tests. Neurosci Lett 392:62–67
8. Palluel E, Nougier V, Olivier I (2008) Do spike insoles enhance postural stability and plantar surface cutaneous sensitivity in the elderly? AGE 30:53–61
9. Priplata AA, Niemi JB, Harry JD et al (2003) Vibrating insoles and balance control in elderly people. Lancet 362:1123–1124
10. Lesemann FHP, Reuter EM, Godde B (2015) Tactile stimulation interventions: influence of stimulation parameters on sensorimotor behavior and neurophysiological correlates in healthy and clinical samples. Neurosci Biobehav Rev 51:126–137
11. Gruzelier JH, Foks M, Steffert T et al (2014) Beneficial outcome from EEG-neurofeedback on creative music performance, attention and well-being in school children. Biol Psychol 95:86–95
12. Zhang Y, Chen Y, Bressler SL et al (2008) Response preparation and inhibition: the role of the cortical sensorimotor beta rhythm. Neuroscience 156:238–246
13. Ninausa MC, Kobera SE, Wittea M et al (2015) Brain volumetry and self-regulation of brain activity relevant for neurofeedback. Biol Psychol 110:126–133
14. Hammond DC (2007) Neurofeedback for the enhancement of athletic performance and physical balance. Am Board Sport Psychol 1:1–9
15. Basta D, Todt I, Ernst A (2007) Characterization of age related changes in vestibular evoked myogenic potential. J Vest Res 17:93–98
16. Rossi-Izquierdo M, Ernst A, Soto-Varela A et al (2012) Vibrotactile neurofeedback balance training in patients with Parkinson's disease: reducing the number of falls. Gait Posture 37:195–200
17. Azarpaikan A, Taherii HR, Sohrabi M (2014) Neurofeedback and physical balance in Parkinson's patients. Gait Posture 40:177–181
18. Goldberg DP, Gater R, Sartorius N et al (1997) The validity of two versions of the GHQ in the WHO study of mental illness in general health care. Psychol Med 27:191–197
19. Macaulaya C, Battistab M, Lebbyc PC et al (2003) Geriatric performance on the neurobehavioral cognitive status examination (Cognistat): What is normal? Arch Clin Neuropsychol 18:463–471
20. Allison B, Neuper C (2010) Could anyone use a BCI? In: Tan D, Nijholt A (eds) Brain–computer interfaces: Human computer interaction series. Springer, London, pp 35–54
21. Reichert JL, Kober SE, Neuper C et al (2015) Resting-state sensorimotor rhythm (SMR) power predicts the ability to up-regulate SMR in an EEG-instrumental conditioning paradigm. Clin Neurophysiol 126:2068–2077
22. Halder S, Varkuti B, Bogdan M et al (2013) Prediction of brain–computer interface aptitude from individual brain structure. Front Hum Neurosci 7:105
23. Dickson CT, Kirk IJ, Oddie SD et al (1995) Classification of theta-related cells in the entorhinal cortex: cell discharges are controlled by the ascending brainstem synchronizing pathway in parallel with hippocampal theta-related cells. Hippocampus 5:306–319
24. Behm D, Colado JC (2012) The Effectiveness of resistance training using unstable surfaces and devises for rehabilitation. Int J Sports Phys Therapy 7:226–241
25. Kennedy PM, Inglis JT (2002) Distribution and behaviour of glabrous cutaneous receptors in the human foot sole. J Physiol 1:995–1002
26. Wu G, Chiang JH (1997) The significance of somatosensory stimulations to the human foot in the control of postural reflexes. Brain Res 114:163–169
27. Merriman NA, Whyatt C, Setti A et al (2015) Successful balance training is associated with improved multisensory function in fall-prone older adults. Comput Hum Behav 45:192–203
28. Wilson ML, Rome K, Hodgson D et al (2008) Effect of textured foot orthotics on static and dynamic postural stability in middle-aged females. Gait Posture 27:36–42
29. Magill R, Anderson D. Motor learning and control: concepts and applications, 10th edn. McGraw-Hill Education