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The Effect of Physical Exercise on Controlling Balance among the Visually Impaired Elderly using Auditory-Vibratory Alarming Feedback Device

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Original Article

Abstract

Introduction: The quality of stability which refers to balance defined as the power to maintain center of mass in relation to base of support. Considering the fact that elderly who are visually impaired encounter problems related to keep balance and its effect on their social activities, the aim of the current research is to study the effect of physical exercise on using audio-vibratory alarming feedback device on controlling balance among the elderly who are visually impaired.

Materials and Methods: Thirty elderly visually impaired whose being impaired is confirmed through taking Snellen test and properties were randomly chosen and divided into two groups to exercise in two situations with physical exercise and physical exercise using biological feedback device. The exercise was of two types of tasks- standing alone or walking along with kinetic and thinking tasks. The elderly chosen for this test participated in post and pre balance test using stabilometr. The groups exercised for 12 weeks and twice a week. To analyze data, we applied analysis variance using repetitive measures (ANOVA).

Results: The results have shown that physical exercise without using biological feedback device have an effect on visually impaired elderly (P = 0.001) Also, physical exercise using biological feedback device have an effect the balance of visually impaired elderly (P = 0.001). The results of independent t between the two groups in post-test test showed a significant difference on balance. I.e. the exercise group using device has shown a better performance related to the balance. (P = 0.035).

Conclusion: We concluded that doing exercises using alarming feedback device can improve balance criteria. In this regard, multi-sensory manipulations based on substitution and adapting approaches can lead to even better results and increase its effectiveness.

Keywords: Auditory-vibratory alarming feedback, Postural balance, Elderly, Visual impairment

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Introduction

Stability is the most important aspect of motion as it is part of all motions (1). The quality of stability, referred to as balance, is defined as the ability to hold the center of mass in relation to the base of support (BOS) (1). Postural control involves the control of body postures in space, which is used for the stability and orientation purposes (2). The postural control efficiency is closely related to the ability to perceive the environment through sensory-environmental systems. The sensory information responsible for this control consists of the somatosensory, visual, and vestibular systems (2). Vision plays an important role in balance, and this is particularly prominent in children, and the ability to maintain balance increases with age among them (1).

The auditory perception and vestibular system are other systems of balance control, composed of two peripheral and central sections which report the angular and linear acceleration of the head (3). The central nervous system (CNS) processes the signals received from the peripheral vestibular system and

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combines them with the visual sensory and proprioception information in order to estimate the head and body orientation (4). Proprioception is another system involved in balance that transmits information about the body motion and posture in space relative to BOS to CNS (1). This system reports the body position relative to the horizontal plane as well as the relationship among different parts of the body relative to each other and includes muscle, joint, and skin sensory receptors (1,2).

Feedback can be divided into the two categories of the intrinsic feedback and extrinsic feedback (5). The intrinsic feedback includes information regarding different aspects of motion that are made available to the performer by different senses of the individual during or after performing the motion (5). Augmented feedback is the information about motion complementary or additional to the intrinsic feedback, including the knowledge of results (KR) and knowledge of performance (KP). KP consists of video, kinematic, biological, and kinetic feedback (5). Biofeedback is a feedback on aspects of motion that can never be received directly. For instance, if a specific biological variable such as blood pressure is measured electronically and used as feedback, then the subjects can learn how to control this variable voluntarily (5). In the elderly people taking painkillers, as well as in the individuals with visual and inner ear impairments with impaired balance, unwanted falls often take place (6).

The medical costs of falls in the elderly impose a heavy financial burden on society and the health care system, in addition to social damage to the community and the individual's associates (6). Evidence suggests that one of the main causes of deaths among the elderly is related to the injuries due to falls, with over 11 thousand deaths worldwide annually (7). Falls in the elderly are devastating and harmful to the economy (8). In the United States, about 16% of people over 65 and under 65 reported a fall at least once in three months, and 31% of those experiencing falls needed medical care, resulting in a 23.3 billion-dollar cost burden a year (8). Although most falls among the elderly do not lead to severe injury and death, their adverse psychological effects can cause fear of subsequent falls and a decreased tendency to perform physical and social activities, i.e. the increased risk of falls, dependence on others, and impaired quality of life (QOL) in the elderly (9). Given the evidence, there is a sharp slope of old age in Iran as in many other countries worldwide (10).

The Office of Aging Affairs, Iranian Welfare Organization reported that in the next 40 years, the elderly will account for a quarter of the country's population (10). In Iran, the population over the age of 65 exceeded 5 million in 2014, which has an increasing trend and the country's elderly population is estimated to reach 25 million people by 2051 (10). This highlights the need to pay attention to the physical health of this segment of society (11). The high importance of falls and the imbalance of the elderly has attracted the attention of many researchers in the development of different interventional programs to reduce the risk of falls (6-9). However, there are scattered findings on the effectiveness of these programs and the content and training methods used seem to be one of the reasons for the dispersion (6). Many studies have reported a link between the improved muscle strength and the strengthened somatosensory receptors with the reduced risk of falls in the elderly (6,12,13), however, little or no effect of training on balance was reported in the study by Latham et al. (14).

Taking into account the results of investigations, one of the reasons for the increased risk of falls in the elderly is the decreased efficiency of the sensory systems involved in balance due to aging (15,16). With age, the sensory systems involved in balance (the visual, somatosensory, and vestibular systems) decline, whereby the body will not be able to detect the deviations of the center of mass and produce adequate and rapid muscle responses to correct posture (17). In a study, Redfern et al. used a dual-task to assess cognitive needs in postural control, and found that age and illness were effective in controlling balance and cognitive needs. Old people often pay more attention to their balance when performing cognitive tasks (18). In a study, Ayres et al. reported that impaired sensory integration was characterized by abnormal sensory processing in the areas of vision, hearing, tactile, olfactory, and taste, with one of the general symptoms being the impaired balance (19). Visual acuity also declines with age. In the meantime, the weakness of the contrast sensitivity and visual depth perception in the elderly is most associated with falls (19). In this regard, Artal et al. conducted a study on individuals with a mean age of 29 and 64 years and found that in the 64-year-old group, light scattering, low image quality, and contrast sensitivity occurred in the retina vision, besides, the eyes encountered decreased liquid and weakness of muscle movements, resulting in the decreased quality of vision among them (20). With increasing age, the sensitivity of the sensory receptors decreases in the ankle and knee joints as well (20). In addition, after the age of 70, vestibular sensory cells decrease by 40% (21). Due to the decline of these sensory systems, which form the basis of proprioception (indicating body position) and kinetic sense, the afferent information available for the postural control is reduced (22). The postural control and balance are a type of sensory-motor function and at high levels of control, the sensory inputs such as the vestibular, visual, proprioception, and sensory information related to the soles are involved in human postural control (22).

Despite the innumerable sensory receptors, the visual system is the superior sense to the other senses. According to Gallahue, vision plays an important role in the balance control and is one of the input forms that can compensate for other sensory deficits (23). Performing a study, Andersson et al. found that in patients with impaired vision and inner ear, for example, the attention to balance control is more affected compared to the healthy individuals (24). Human dependence on vision is so strong that other sensory information may be neglected, even with paying attention to it (24). Impaired vision and its inaccurate performance as well as decreased attention are among the factors that lead to falls (24,25). Conducting a study, Yardley et al. argued that the vibratory-sensory feedback for postural control is a small and valid sample, however the interference between the use of the vibratory-sensory feedback and the second task implementation in groups and individuals with different age-related complications is still unclear (26).

Evidence suggests that managing good eyesight provides an effective strategy to reduce falls in the elderly. Given the shortcomings mentioned in the elderly, and in particular the decline in visual function as the main sense of balance, can the reinforcement of the other senses as a solution to cope with weakness, impairment, or age-related disorders, injury, or illness reduce the risk of falls in old people with a weakness in balance? Overall, the balance for the elderly, which is on the one hand a serious issue needing attention and on the other hand need investigations, is of high importance, in addition, the elderly have limitations, deficits, or problems in one or more of their senses (6,19). With regard to the biofeedback functions, it can be concluded that the research seems more urgent on the elderly in this area, and especially for those with the impaired vision, in order to compensates for the deficiency or limitation of the balance information and help them enhance their balance using a feedback device in the lumbar region and at the vertebrae L1 and L3 (1 to 3 lumbar vertebrae) of the body. So, the question now arises as how does the use of a biofeedback device in the form of a belt to help the elderly by giving an augmented vibrational-auditory feedback to their body affect their balance and ultimately their falls? Therefore, the present study was carried out to determine the effect of physical exercise using the auditory-vibratory alarming feedback device on balance control in the elderly subjects with an impaired vision.

Materials and Methods

This study was an experimental-clinical trial conducted to examine the impact of the biofeedback on balance control in the elderly with an impaired vision. The study inclusion criteria included 20/70 vision within 3 m of the Snellen chart, performing the examinations without any assistance, no lower extremity fractures, lack of ear problems leading to imbalance, no cardiovascular diseases (CVDs) impeding the exercise (27), not using nerve drugs, and avoiding intense exercise and rehabilitation activities during the study (27). The participants included the 65-74 year old elderly men living in Mahabad, Iran, who were sampled to participate in the study voluntarily and with convenience sampling method. The sample size was estimated to be 30 people using Cochrane’s formula (30). The project was approved in the research council with code of ethics IR.SBU.ICBS.97.1035 from Cellular and Molecular Biology Research Center (CMBRC), Shahid Beheshti University of Medical Sciences, Tehran, Iran, and registered on the Iranian Registry of Clinical Trials (IRCT) site with Code IRCT20190107042265N1. In the next step, the study objectives were explained to the subjects and they declared their willingness to participate in the study and then the data were collected. Additionally, the participants were assured that their identities and information would remain confidential.

The tools utilized in the study included the personal information and consent forms, medical documentation, a sheet containing briefing instructions, a stabilometer, the researcher-made biofeedback device, headphones, an elastic belt, a personal computer, an optometry device (Plusoptix S09, Germany), and the Snellen chart.

The exercise was performed in two modes of physical training with the auditory-vibratory alarming feedback device and physical training without using the biofeedback.

The visual screening tests were performed using the Snellen chart and the optometry was conducted by an optometrist using the optometry device. Then, the balance test was performed using the stabilometer in the two pre-test and post-test stages. The static balance meter had a square size of 40 × 40 cm and four sensors in its four corners and measured the amount of forward, backward, left, and right oscillations in percent and cm. For data collection, a static balance test was performed as the pre-test for all subjects in the same condition by the stabilometer. Based on the stabilometer guidelines, the subjects had to stand with their bare feet on the device for 30 s to perform the test, looking at a specified point on the wall at an elevation proportional to their height (the point was considered to prevent the individual's eyes movement towards the surroundings, as any movement of the head causes the center of mass displacement). To increase reliability, each subject was tested three times and the mean value of the three values was recorded. Regarding the validity and reliability of the device, setting the values of $\alpha = 0.5$ and $\beta = 0.2$, as well as three times of evaluation, the minimum acceptable reliability level was 0.70.

Taking into account the obtained mean values and according to the physical and visual impairment criteria, the participants were divided into two groups of physical training and physical training with the biofeedback device, with each group consisting of 15 subjects. The two groups performed the desired exercises in 12 one-hour sessions during 45 days. When performing the pre-test and post-test, one person was placed next to the stabilometer to prevent subjects from falling. All tests (exercise and core tests) were carried out on days when the subjects were not on long rest and did not use high doses of analgesics (27). All pre-test, training, and post-test stages were performed in the spring of 2018 at the Mahabad corrective exercise center affiliated to department of education. The exercises consisted of four walking exercises and three standing exercises, each containing five repetitions per session.

The participants performed 50 m of walking, standing up and walking without changing direction and without leaning against something, walking with a dual cognitive function such as countdown from seven (27), and walking with another motor action such as carrying a glass of water along a distance of 25 m. In addition, standing with both feet held together for 30 s, standing on a 3-cm thick foam for 30 s, and standing on one leg for 30 s were performed (27).

Operation and features of the auditory-vibratory feedback device: This device included a software application installed on an Android-based cellphone that used the trunk vibrations as a measure of upright position measured by the accelerometer sensors embedded at L1 and L3 lumbar vertebrae levels to check balance. Accordingly, the center of mass was located at 55% of an individual's height in a location between the L1 to L3 lumbar vertebrae (29). This point, specified as the center of mass by the angular velocity sensors, was chosen as the belt installation site (29). The sensors on the headphones that were placed on the belt showed the trunk states at the front-back and mid-lateral angles in the normal standing position of the individual and when the body was out of balance (calibrated at 90% balance point in this test), a vibration along with a sound was transmitted to the subject's ears by the headphones, which was a criterion for recognizing the loss of balance and the vibration of the subject's trunk.

Descriptive statistics were employed to classify and arrange the data, calculate the central and dispersion indices, and separate the groups. Moreover, the Shapiro-Wilk test, repeated measures analysis of variance (ANOVA) test, and t-test were used to evaluate the normal distribution of data, examine the difference between the pre-test and post-test of the groups, and examine the differences between the two groups, respectively. The data were analyzed by SPSS software (version 18.0, SPSS Inc., Chicago, IL, USA) and $P < 0.05$ was considered as the data significance level.

Results

The demographic characteristics of the participants are presented in table 1.

The data was checked using the Shapiro-Wilk test and all of the ANOVA assumptions were valid ($P > 0.05$). Therefore, the parametric inferential statistical methods were applied for further investigation.

Table 1. Mean demographic variables of participants

Response type	Exercise	Device + Exercise
Response quantity	Mean ± SD	Mean ± SD
Age (year)	72.7 ± 2.4	71.5 ± 2.5
Height (cm)	175.8 ± 4.5	176.2 ± 3.4
Weight (kg)	77.8 ± 3.6	78.9 ± 3.4

Based on the data presented in table 2 and since the P value for the tests was greater than the significance level ($P = 0.05$), the assumption of normal distribution of the data was accepted and parametric methods could be used to test the hypotheses. In the present study, t-test, which is a parametric test, was utilized to analyze the study hypotheses.

Furthermore, the Levene test was used to evaluate the equality of variances. Accordingly, the significance level was greater than 0.05 in all variables, indicating the homogeneity of variances of the groups (Table 3).

Table 2. Results of normality test of the variables studied using Shapiro-Wilk test

Variable	Group	Test value	P value
12 practice sessions	Pre-test	0.952	0.691
12 sessions of exercise using the biofeedback device	Pre-test	0.874	0.540
12 practice sessions	Post-test	0.639	0.322
12 sessions of exercise using the biofeedback device	Post-test	0.755	0.508

Table 3. Levene test results to test the equality of variances

Variable	df1	df2	P value
12 practice sessions	28	1	0.190
12 sessions of exercise using the biofeedback device	28	1	0.232
12 practice sessions	28	1	0.135
12 sessions of exercise using the biofeedback device	28	1	0.210

Repeated measures ANOVA was used to compare the effect of 12 sessions of training using the biofeedback device in the pre-test and post-test stages. On the basis of the findings reported in table 4, the main effect of the pre-test and post-test stages had a significant effect on the balance of the visually impaired elderly (P = 0.001). Besides, the direct effect of group (P = 0.001) was significant on the balance of the elderly with a visual impairment. Finally, the interaction effect between the stages and group also had a significant effect on the balance of the elderly with a visual impairment (P = 0.001) (Table 5).

The independent t-test was adopted to compare the two groups with and without the device in the post-test stage. Based on this test, the mean balance of the training groups with and without the device were 10.84 ± 2.05 and 7.35 ± 3.23, respectively and there was a significant difference between the two groups in the post-test stage (P = 0.001, t = 1.18). Since the significance level obtained was less than 0.05, it can be concluded that 12 training sessions with the biofeedback device had more effect on the visually impaired elderly compared to 12 training sessions alone.

Discussion

The study findings showed that there was a significant difference between the groups in terms of the balance score. Both groups showed improvement in performance with exercises and achieved significant balance results. There was also a significant difference between the two groups in performing the balance test. This difference was associated with the improvement of the balance of the group with training using the auditory-vibratory feedback device, which was different from the physical training group alone.

The results of hypothesis analysis showed that the elderly with a visual impairment had a weakness in balance and with physical training, they showed a significant difference between the pre-test and post-test stages in the balance test. In a study, Gauchard et al. claimed that the impaired vision system, known as the superior sense in balance control, causes the elderly to face problems in performing their daily tasks, the most important being falls (25). The experience of impaired vision in the elderly has been proven in numerous studies (17,19-25). In his book, Gallahue states that physical systems decline and lose performance in the old age (23). Given the results of the first hypothesis, which examined the effect of 12 sessions of physical training on the balance of the visually impaired elderly, in people with visual impairment caused by the aging processes, improvement in performance was observed as a result of the exercises. Using the balance exercises as well as different levels of training during the exercises that included strengthening other balance subsets, the individuals had less balance faults and lack of concentration after getting acquainted with and performing the exercises. However, their performance was associated with a decline on the exercises involving the dual-task of mathematical countdown along with maintaining balance and also standing on the foam as well as standing on one foot.

Table 4. Repeated measures analysis of variance (ANOVA) test results to compare the training stages without using the biofeedback device in the experimental and control groups

Scale	Source of effect	Sum of squares	df	Mean squares	F	P value
12 sessions of training without the biofeedback device	Stage	135.24		67.62	17.00	0.001*
	Group × Stage	31.30	2	7.82	2.00	0.001**
	Error	164.25	28	3.91	-	0.001
	Group	47.16	1	23.58	2.42	0.001***
	Error	203.82	14	9.70	-	0.001

** Difference in test stage, ** Difference in test stage and group, *** Difference in group stage

Table 5. Repeated measures analysis of variance (ANOVA) test results to compare the training stages using the biofeedback device in the experimental and control groups

Scale	Source of effect	Sum of squares	df	Mean squares	F	P value
12 sessions of training with the biofeedback device	Stage					
	Group × Stage	137.55	4	34.39	13.02	0.001**
	Error	180.85	42	2.63	-	0.001
	Group	399.28	2	199.64	14.18	0.001***
	Error	295.28	21	14.07	-	0.001

** Difference in test stage and group, *** Difference in group stage

Artal et al. suggested that in people with balance deficits, rehabilitation exercises should be used while maintaining stability and walking symmetry. These exercises are useful and improve their performance. Analyses of their test data were indicative of a better balance of the subjects in the tasks that only examined the balance and experienced more imbalance at the secondary task. The impaired vision and the concurrent problem of the sensory organization in the elderly as well as the visual and motor impairments mean that intervention in these individuals should focus on improving the efficiency of proprioception and hearing sense (20), as performed in the present study.

In the present study, the facilitation of the vision impairment adaptation strategies and replacement of the auditory and proprioception systems were highlighted and the improved results in different tests and exercises with different sensory conditions indicated this performance improvement. The better implementation of the tests during the training sessions in different situations in the vision impairment conditions shows that the physical training intervention and physical strengthening have been more effective in using the senses and have been able to work more effectively in the absence of complete vision or in the condition of the altered proprioceptive inputs. The results of investigations have shown that in both childhood and old age, dependence on the sense of sight is greater than other senses, and the loss of performance in cases with closed eyes confirms this (26). It seems that the frequently experienced falls in the elderly with a vision impairment and the reliance on the visual system in these individuals may be due to the age and functional impairments of the visual system, which is one of the main systems of balance control in this age group and the underperformance in this system causes the increased reliance on other inputs (such as hearing and proprioception) (15). Furthermore, anomalies or vision impairment can appear as an inflexible weighting of the sensory information for orientation that may greatly make the individual depend on a special sense for postural control. In the lack of that sense or its improper function in a situation, the person will continue to rely on that preferred sense, even if it results in instability (30), but attending a training course could result in the significant reduction of dependence on the visual data. In addition, there was a significant difference in training tasks and a change in the reduction of the proprioceptive inputs in the absence of complete vision (standing on one foot on the foam with eyes closed), meaning that people with better training were able to use other senses, in particular the proprioception. The decline in the sensory and neuromuscular control mechanisms may be one of the reasons for the increased muscle activity. The increased levels of muscle activity may contribute to the increased joint proprioception by the firing rate and use of the primary afferents, thereby enhancing the functional behavior associated with the postural control mechanisms (31).

In the present study, stimulation of the mechanical receptors and foot pressure by training on a 3 cm foam improved the somatosensation and, consequently, improved the balance indices and the improvement in the test on one foot only with the proprioception showed this improvement. Pinnington et al. reported that the walking exercise on soft sand could improve the lower extremity strength and balance by stimulating and further utilizing the proprioceptive information (32). Additionally, the investigations by Farsi et al. revealed that the balance training intervention could be an effective approach to improving risk factors for falls and developing safety in the elderly (33,34). The findings of the present study are consistent with those reported in the two above studies. Another possible reason for the improvement of balance function in these individuals seems to be the central integration achieved by the training and coordination exercises allowing for better motor responses (24).

A significant difference was observed in the physical training group with the auditory-vibratory (biological) feedback device in terms of balance in comparison to pre-test. Moreover, the study findings suggested that there was a significant difference between the two groups, and the physical training group with the device that used the combined exercise with the immediate biofeedback showed better balance results. Between the two experimental groups, only one group received the biofeedback, achieving better results in balance.

In their study, Zhou et al. conclude that the balance oscillations increase when standing with the eyes closed and that one of the reasons for improving the balance in the combination training group may be the use of small vibrating sensors, as it seems that training with a feedback device causes the stimulation of the proprioceptive and kinetic receptors of the lower extremity joints (35), which is in line with the findings of the present study.

The results of the current study support the concept of the hierarchical weighting of the sensory inputs for postural control based on their relative accuracy in reporting the body movements and position in space. In environments and situations in which accurate and optimal information on the body movements, position, and posture is not provided due to the physical conditions and deficiencies of various senses, the weight assigned to that sense as a source of body orientation and posture, reduces; while the weight of the other senses should be more precise and increased. Due to the increased senses available to orient and the ability of the CNS to alter the relative importance of any sense for the postural control, individuals will be able to maintain their postural stability in different environments.

Limitations

One of the limitations of the present study was the small number of subjects, hence it is suggested that further studies be performed on more individuals. Besides, medications and sleep disorders were other limitations that were not controlled.

Recommendations

As the function of the nervous and sensory systems changes in the learning process, it is recommended that these systems be recorded in future studies to determine the adaptation and performance changes in these individuals. Since aging has a very wide range of areas and only the balance was investigated in the present study, it is recommended to address other problems of the elderly in both sexes with a larger sample size.

Conclusion

The elderly people with a vision loss are able to improve their balance, and physical exercise with feedback is more useful for improving the balance compared to the exercise alone. Moreover, such a balance is accompanied by a higher level of stability. Exercise along with receiving feedback, with increasing the individual's motivation to continue training and increasing the sensitivity of the proprioception and auditory sense systems to maintain and restore balance, provides a more appropriate strategy to balance maintaining coordination training to the therapists. Practical results of the present study included an increased motivation for developing training protocols for these individuals with regard to their ability to improve performance. It is also recommended to reduce the dependence of the elderly with a visual impairment on visual inputs through sensory stimulation and intellectual and computational tasks, as in addition to reduced trunk fluctuations, it also reduces the visual dependence in these subjects.

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Authors' Contribution

Hadi Gevorky: Study design and ideation, manuscript arrangement and evaluation in scientific terms, data collection, support and execution services, sample and data collection, final manuscript approval for submission to the journal office, responsibility for maintaining the study integrity from beginning to end, and responding to reviewers; Alireza Farsi: Study design and ideation, expert evaluation of the manuscript in terms of scientific concepts, and final approval of the study for submission to the journal; Behrouz Abdoli: analysis and interpretation of the results and specialized scientific evaluation of the manuscript. Shirko Sori also cooperated in the study as a physiologist.

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Conflict of Interests

The authors declare no conflicts of interest. Hadi Gevorky was a Ph.D. Student, School of Sport and Health Sciences, Shahid Beheshti University of Medical Sciences. Alireza Farsi and Behrouz Abdoli were faculty members of Shahid Beheshti University of Medical Sciences and Mr. Shirko Sori was a physiotherapist.

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