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Comparison of the effects of explicit and implicit learning on the balance of the elderly

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Abstract

Background: In recent years, the examination of the impact of various types of different exercises as the key influential components on balance has gained considerable popularity. Numerous studies have investigated the effects of diverse exercise modalities on the enhancement of balance abilities.

Aim: The aim of this research was to compare the effects of different types of learning (explicit and implicit) on the balance of elderly individuals.

Materials and Methods: Forty-two elderly participants (both women and men), after initial health assessments and medical history reviews, voluntarily participated in the study. They were randomly assigned to three groups: explicit learning group (14 participants), implicit learning group (14 participants), and control group (14 participants). Before the implementation of the targeted learning exercises, the static balance of the participants was assessed using the Flamingo Test, and dynamic balance was measured using the Timed Up and Go (TUG) test. After two sessions of learning exercises, the participants were reassessed. Statistical analysis was conducted using descriptive statistics (mean and standard deviation) and inferential statistics (ANCOVA and Shapiro-Wilk test) at a significance level of $P<0.05$.

Results: The findings indicated that there was no significant difference between the groups in the pre-test, but after performing the learning exercises, the static balance of the implicit learning group showed a statistically significant improvement compared to the explicit learning group and the control group. However, there was no significant increase in dynamic balance performance in any of the groups.

Conclusion: The results of this study support the claim that implicit learning exercises can have a positive and significant impact on the static balance performance of elderly individuals. It was also shown that implicit cognitive training had no effect on dynamic balance, which may indicate the important role of other variables such as motor control abilities.

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1. Introduction

Balance is a critical skill in the daily lives of individuals, comprising a combination of incoming sensory information, awareness of the surrounding environment, and awareness of the position of body parts in space [1]. This skill depends on the reception and processing of information from the deep sensory (proprioceptive), visual, and vestibular systems, as well as muscular strength and the ability to react quickly to external stimuli. When these incoming sensory inputs are combined, an appropriate motor response is generated for controlling the body's position and posture, a complex process that can be explained based on the theory of internal systems-based motor control [2] and models of complex systems [3].

In accordance with the theory of neuromuscular aging [4], these functional capabilities exhibit a gradual decline with advancing age, culminating in a progressive reduction in the ability to maintain balance and a heightened propensity for falls among the elderly [1]. Extant research indicates that approximately 30% of individuals aged 65 and above, and 50% of those aged 80 and above, experience at least one fall per year [5]. These falls not only diminish quality of life, self-confidence, and overall functioning, but also impose a substantial burden of physical and psychological needs upon society, often accompanied by significant morbidity and mortality [6, 7]. For instance, the direct and indirect healthcare costs associated with falls among the elderly in the United States are estimated to reach around $50 billion annually, while in Canada, the figure is estimated at approximately $2 billion per year [8]. Consequently, the issue of balance and falls in the aging population has emerged as one of the most pressing healthcare concerns in modern societies.

The research conducted on the elderly and postural control has revealed several challenges in this domain. One such challenge pertains to the researcher's definition of aging and disability, and the difficulty in clearly distinguishing between healthy older adults and those with pathological conditions [9]. This issue can introduce ambiguity into studies involving this age group. Furthermore, balance control may be associated with a decline in the cognitive component of motor adaptation as individuals advance in age. This is because the process of maintaining balance is gradually and somewhat automatically regulated during childhood, whereas in late adulthood and old age, preserving postural equilibrium often necessitates heightened conscious awareness and control [2].

According to the parallel processing theory [10], the aging process leads to a reduction in the brain's capacity to concurrently process multiple streams of information. This decline in parallel information processing is believed to underlie the deterioration of the cognitive component in motor adaptation. Specifically, as individuals grow older, they experience a decreased ability to simultaneously integrate and utilize the various sensory inputs (e.g., visual, proprioceptive, vestibular) required for precise body control and postural maintenance [10]. This impairment in the concurrent processing of multisensory information contributes to the diminished cognitive resources available for the successful adaptation of motor skills, ultimately manifesting in the balance and postural control challenges observed in the elderly population.

Other studies (fMRI and MRI) have

shown that for different mental and physical processes, different regions of the brain exhibit specific activities, the effects of which have been investigated in learning [11]. In general, learning is an important process at all stages of life, defined as "relatively stable changes in mental, behavioral, or emotional performance" [12]. Learning takes place in different ways throughout life, and studies have shown that when an individual is exposed to an environment with principles and rules, they can acquire the structural rules related to environmental stimuli and ultimately learn them implicitly without being able to verbally express these rules [13].

Implicit learning is contrasted with explicit learning, which is presented to the learner through visualization, demonstration, feedback, and verbal guidance [14]. In fact, learning, especially in motor skills, plays an important role in the individual's adaptation and adaptation to the environment. However, the difference between explicit and implicit learning is one of the important issues in this field, as explicit learning, which is performed deliberately and with effort, is impaired with increasing age. In contrast, implicit learning is somewhat automatic and is less affected by aging [15].

Studies have shown that implicit learning may have greater benefits for improving the balance performance of the elderly. For example, Allahverdipour et al. (2021) found that in healthy older adults, additional cognitive loads reduced the performance of dynamic balance, while physical loads had no effect [16]. This suggests that maintaining balance in old age requires increased awareness and conscious control. In contrast, implicit learning may lead to greater automatization of motor skills and impose a lower cognitive burden on the individual. Furthermore, studies have shown that in challenging conditions, implicit learning may have greater benefits. For instance, Verneau et al. (2014) reported that older adults were able to maintain better balance performance after implicit learning, especially under time pressure [17].

Additionally, in the study by Abdoli et al. (2004), the effect of implicit and explicit learning on the serial reaction time of 66 participants was investigated. Although the difference between the groups was not significant, the authors stated that in complex skills, implicit learning had at least as much impact on individual performance as explicit learning [18]. On the other hand, some studies have shown that in the initial stages of learning, there is not much difference between explicit and implicit learning. For example, Nazemzadegan and Yousefi (2020) in a study on children found that while both explicit and implicit learning led to improvements in static balance, no significant difference was observed between the two methods [19].

Furthermore, Jie et al. (2020) evaluated the effects of explicit and implicit motor learning interventions on the walking of older adults after stroke. The results showed that the provision of both explicit and implicit motor learning interventions was successful, and improvements in walking were observed in both groups [20].

In summary, the available evidence suggests that both implicit and explicit learning methods can be beneficial for improving the balance performance of the elderly, but implicit learning may have greater advantages in challenging and complex situations. This is because implicit learning leads to greater automatization of motor skills and imposes a lower cognitive burden on the individual.

Therefore, attention to the elderly age group and understanding the important factors for creating a better quality of life for them can significantly improve the health of the elderly and the community. Therefore, in the present study, we tried to examine the types of learning (explicit and implicit) and their effect on the balance (static and dynamic) of the elderly in more detail. Thus, in this study, interventions that engage the processing and cognitive components of the elderly will be provided. Since there is currently no literature that has examined the effectiveness of explicit and implicit learning through cognitive interventions on the balance of the elderly, the present study aimed to determine whether learning tasks (explicit and implicit) are effective on the balance of the elderly and, if so, whether there will be a difference in the degree of influence of the type of learning (explicit and implicit) on the balance of the elderly. It is hoped that the results of this study will provide new insights for instructors and trainers who work with the elderly and the disabled.

2. Materials and Methods

2.1. Participants

The statistical population for this study comprised elderly individuals aged 60 to 70 years residing in the city of Shiraz. A total of 42 participants (mean age: 64.2±7.85 years) were selected through cluster sampling from various centers for elderly care. Participants were recruited on a voluntary basis after completing questionnaires that assessed their medical history, physical activity, and demographic characteristics.

Inclusion criteria for participation included being aged between 60 to 70 years and providing informed consent to partake in the study. Individuals with any cognitive or physical impairments that could hinder their ability to complete the study procedures were excluded.

To determine the sample size, G*Power software was utilized. The study was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki, and all participants provided written informed consent prior to their involvement. The study protocol received approval from the local ethics committee.

2.2. Instrument

2.2.1. PARQ Questionnaire

The Physical Activity Readiness Questionnaire (PARQ) was used to assess the physical readiness of participants for involvement in the research. The reliability of the PARQ questionnaire among elderly individuals was demonstrated over a one-week period, with a reliability coefficient of 0.74 [21]. Additionally, a study conducted by Tahmasebi et al. (2024) reported satisfactory validity for the questionnaire [22].

2.2.2. Medical history questionnaire

This researcher-developed questionnaire, consisting of 14 questions, is designed to gather information about the central nervous system, vision, hearing, medical history, and medication use in order to assess the participants' balance status.

2.2.3. Demographic and Anthropometric measures

A demographic form was used to collect individual information including year of birth, weight, height, and body mass index.

A Xiaomi mi-smart-scale2 with a measurement accuracy of 0.1 grams was used to measure weight, and a Frolik wall-mounted stadiometer was used to measure height.

2.2.4. Static balance test: Flamingo test

The participant stood on their dominant leg with eyes closed (the flamingo movement). The participant placed their hands on their waist, lifted the heel of the other foot, and placed it on the shin of the supporting leg. The static balance score was determined by the duration for which the participant could maintain this position without losing their balance or removing their hands from their waist. A stopwatch model ProS 011 was used to measure the duration of the static balance test. The validity and reliability of the Flamingo test have been well-established in the literature. A systematic review by Springer et al. (2007) reported that the Flamingo test has excellent test-retest reliability, with intraclass correlation coefficients ranging from 0.75 to 0.93. Additionally, the test has been shown to have good concurrent validity with other measures of static balance [23].

2.2.5. Dynamic Balance Test: Timed Up and Go (TUG)

The TUG test was used to assess dynamic balance. In this test, the participant was instructed to rise from an armless chair, walk a distance of 3 m, turn around, walk back to the chair, and sit down without using their hands. A stopwatch model ProS 011 was used to measure the duration of the TUG test, and an armless chair was used for the test.

The TUG test measures the time (in sec) it takes for an individual to complete this sequence of movements, which reflects their dynamic balance and mobility [24].

The validity and reliability of the TUG test have been well-established. A systematic review by Steffen et al. (2002) reported that the TUG test has excellent test-retest reliability, with intraclass correlation coefficients ranging from (0.70) to (0.99). Additionally, the TUG test has been shown to have good concurrent validity with other measures of dynamic balance and mobility [25].

Scoring: A lower time to complete the TUG test indicates better dynamic balance and mobility. Normative values for the TUG test have been established, with longer completion times indicating increased fall risk [24].

2.2.6. Explicit and Implicit learning assessment instrument

In this study, a device designed according to the article by Jongbloed-Pereboom et al. (2017) was used to create types of explicit and implicit learning [26]. This device consists of two essential components as follows:

Keyboard
- Size: 33×33 cm
- Number of keys: 9 illuminated keys (each 7×7 cm)
- Distance between buttons: 3 cm

Control Unit
- Includes two microcontrollers: one for executing tests and measuring time, and the other for storing results
- The score report includes the duration of each test sequence, total time, number of errors, and error times in TXT format

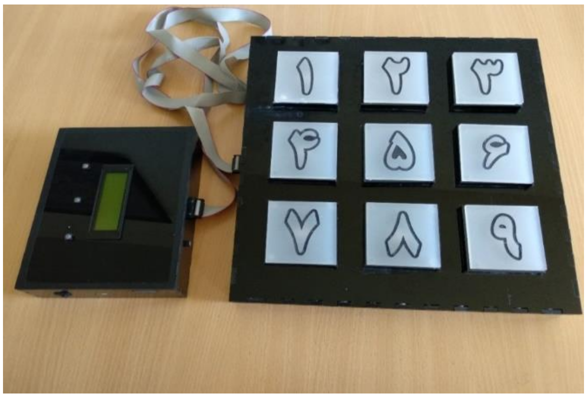

Figure 1. Device for examining explicit and implicit learning

Depending on the selected test, the

device uses specific algorithms to randomly or according to a predetermined pattern illuminate the lights. If the correct key is pressed, the light turns off, and the test proceeds to the next stage. Otherwise, an error is recorded, and the test does not continue until the correct key is pressed.

2.3. Procedure

2.3.1. Test execution method

Before conducting the explicit and implicit learning interventions, a pre-test for static and dynamic balance was performed for all participants. After that they were randomly divided into three groups: explicit learning group (14 individuals), implicit learning group (14 individuals), and control group (14 individuals). The entire protocol included four sessions: one pre-test session (static and dynamic balance), two practice sessions (explicit and implicit learning), and one post-test session (static and dynamic balance). During the test, participants engaged in no activities other than their daily routines.

2.3.2. Protocol for explicit learning training group

Elderly individuals were seated individually on chairs, and a device for explicit and implicit learning was positioned at an appropriate height for each participant. In this protocol, participants were tasked with discovering a specific sequence through trial and error. When a participant pressed the correct button, a light would illuminate, signaling that they could proceed to the next button in the sequence. If the wrong button was pressed, no light would activate, prompting the individual to continue searching for the correct button.

The pattern of illuminating the keys consisted of five blocks of five sequential trials, including the numbers 2, 8, 5, 9, and 4. Each time a number in the pattern was pressed, the time was recorded. After all numbers in the pattern were identified, the total time was calculated and stored in the device. The test concluded after three trials with the same pattern.

In the explicit learning protocol, after recognizing the pattern of illuminated lights, participants demonstrated faster responses, and their total times decreased. This decrease in reaction time indicated the development of explicit learning, as participants consciously recognized and could articulate the pattern of the lights. The training session comprised 5 blocks, totaling 25 trials (Table 1).

After a 10-min break, a retention test was conducted, consisting of 3 blocks and 15 trials (Table 2).

Table 1. Explicit learning training group trials

Block	Trial type	Number of trials
1	Sequential	5 (3 sequential trials, 2 sequential trials)
2	Sequential	5 (3 sequential trials, 2 sequential trials)
3	Sequential	5 (3 sequential trials, 2 sequential trials)
4	Sequential	5 (3 sequential trials, 2 sequential trials)
5	Sequential	5 (3 sequential trials, 2 sequential trials)

Table 2. Retention test for explicit learning

Block	Trial type	Number of trials
1	Sequential	5

		(with the same order as the previous trials)
2	Sequential	5 (with the same order as the previous trials)
3	Sequential	5 (with the same order as the previous trials)

Table 3. Implicit learning training group trials

Block	Trial type	Number of trials
1	Sequential	5
2	Sequential	5
3	Sequential	5
4	Sequential	5
5	Sequential	5
6	Random	2
7	Random	5
8	Random	5

Table 4. Retention test for implicit learning

Block	Trial type	Number of trials
1	Sequential	5
2	Sequential	5
3	Sequential	5
4	Random	2
5	Random	5

2.3.3. Protocol for Implicit Learning Training Group

In the implicit learning protocol, elderly individuals also sat individually on chairs, with the device for explicit and implicit learning positioned at an appropriate height. Participants were instructed to press the button that illuminated as quickly as possible, without needing to discover a sequence. In the implicit learning protocol, the lights were automatically turned on with a variable pattern. The practice session consisted of five consecutive blocks of five trials with three random blocks (one block of two trials and two blocks of five trials) where the keys were lit randomly without a pattern. The other two blocks that were lit consecutively included the numbers 3, 5, and 7. After several trials, the participants learned how to turn off the lighted keys without realizing the pattern of the keys being turned on. As a result, creating memory is how to turn off and create learning, which indicated the creation of learning in the participants. The training session consisted of 8 blocks and a total of 37 trials (Table 3).

After a 10-min break, a retention test was conducted, consisting of 5 blocks and 22 trials (Table 4).

2.4. Statistic

In the present study, first, the descriptive statistics of the measurement variables were examined. To answer the questions, the Shapiro-Wilk test was used to check the normality of the data, and analysis of covariance was used to examine the between-group changes. It is worth noting that the assumption of homogeneity of variance (sphericity) was examined based on the Mauchly's test. Then, to determine the exact location of the difference between the research sessions, the Bonferroni post-hoc test was used. The significance level for all tests was set at P=0.05. The statistical calculations were performed using SPSS software version 26.

3. Results

Overall, the study included 23 female and 19 male participants, for a total sample size of 42 individuals. The mean age of the participants was 64.7 years (SD=2.85), the average height was 164.31 cm (SD=9.03), and the mean weight was 72.69 kg (SD=10.16).

After examining the normality of the data, homogeneity of variances, and homogeneity of regression slopes, the results of the ANCOVA analysis indicated a statistically significant difference in static balance performance among the three groups (F=5.340, *P*=0.009) with a medium to large effect size (η^2=0.219). Bonferroni pairwise comparisons revealed that the implicit learning group performed significantly better in the static balance test compared to the control group (*P*= 0.022) and the explicit learning group (*P*= 0.021). Regarding dynamic balance, the Analysis of Covariance showed no statistically significant differences between the three experimental groups (F=0.150, *P*=0.861), with a very small effect size (partial η^2=0.008).

In summary, the implicit learning group demonstrated the best performance on the static balance test, as evidenced by the significant differences in pre-test and post-test scores compared to the control and explicit learning groups. However, no significant differences were observed between the groups in dynamic balance performance (*P*>0.05).

Table 5 presents the frequency distribution of participant gender across the three experimental groups: control, explicit learning, and implicit learning. Overall, the study included 23 female and 19 male participants, for a total sample size of 42 individuals.

Table 5. Frequency distribution of participant gender in each group

Gender	Control group	Explicit learning	Implicit learning	Total
Female	6	9	8	23
Male	8	5	6	19
Total	14	14	14	42

Table 6. Descriptive statistics of the research variables in the control group, explicit learning, and implicit learning

Measure	Group	Pre-test		Post-test	
		Mean	SD	Mean	SD
Static balance	Control	2.205	1.081	2.372	0.959
	Explicit	2.176	1.003	2.352	0.783
	Implicit	1.804	0.935	3.255	1.749
Dynamic balance	Control	6.527	1.042	6.449	0.822
	Explicit	6.703	1.035	6.397	0.842
	Implicit	6.661	0.929	6.495	1.179

Table 7. Bonferroni pairwise comparisons for static balance

Pair	Mean difference	Std. error	Sig.
Control group × Explicit learning	0.001	0.399	1.00
Control group × Implicit learning	-1.149	0.405	0.022*
Explicit learning × Implicit learning	-1.149	0.404	0.021*

4. Discussion

The significant effect of different types of learning is a confirmation of the brain components involved in balance control. A possible reason for implicit learning being more effective on static balance than explicit learning could be related to the ability of implicit learning to keep the working memory capacity empty. According to the implicit learning view [27], when an individual learns a task implicitly, they do not need to employ working memory capacity during performance, and consequently, they will not require conscious effort to execute the skill [28]. If the individual is then placed in a challenging situation that requires the use of working memory capacity, the task will be performed easily without a decrease in performance. This characteristic of implicit learning, where there is no need for working memory, can lead to improvements in static balance. Static balance also requires the use of working memory capacity. By freeing up working memory capacity, implicit learning allows for greater focus on balance control, resulting in improved static balance performance [29, 30].

Contrary to this type of learning, researchers argue that practicing a task explicitly requires the individual's conscious effort and the conscious use of working memory capacity. The learned task through this method will result in a decrease in performance and execution in a situation that requires conscious problem-solving, due to the lack of working memory capacity [31]. Another possible reason for the improved performance in the implicit condition could be related to the expansion of working memory capacity in the implicit training conditions [32]. It has been shown that working memory capacity decreases with aging [33], and it has also been shown that this capacity can be increased with cognitive or even motor training [34, 35]. It is possible that the training used in this study led to an expansion of working memory capacity, and since the training was implicit (with the rationale that implicit training occupies working memory capacity less), greater progress was seen in the participants' performance compared to the explicit training.

In dynamic balance, no difference was observed between the two types of learning. Essentially, these two types of learning did not show any effect on dynamic balance. At first glance, these findings may seem contradictory, as one could argue that dynamic balance requires the use of more working memory capacity compared to static balance, and therefore, a difference between the two groups should have been observed in this test. However, a closer look can provide a logical explanation for this seemingly contradictory finding. The task used in the dynamic balance assessment was likely more dependent on the expansion of motor control capacities (muscle strength, increased range of motion, joint and tendon flexibility) than the expansion of cognitive capacities; these are capacities that have been shown to be greatly affected by aging [36]. It is possible that the application of a motor task, either implicitly or explicitly, would have a greater effect on this type of balance compared to a cognitive task (implicit or explicit).

Overall, the results of the present study support the claim that implicit cognitive training can have a positive and significant effect on the static balance performance of the elderly. This effect can be due to the improvement in the working memory capacity of the elderly, which has been shown to experience a significant decrease during this period [37]. It was also shown that implicit cognitive training did not affect dynamic balance, which can point to the more important role of other variables such as motor control abilities [38].

5. Conclusion

The findings of this study provide several practical implications and recommendations for future research. Given the significant effect of different types of learning on balance performance in older adults, the results suggest that incorporating both implicit and explicit learning approaches into rehabilitation programs may be beneficial. Specifically, the superior impact of implicit learning on static balance indicates that training protocols emphasizing implicit skill acquisition could be an effective strategy for improving postural control in the elderly. Practitioners such as physiotherapists, occupational therapists, and fitness instructors working with older adults should consider designing exercises that have a greater cognitive and processing demand relative to the motor component, as this may lead to greater working memory capacity expansion and, consequently, enhanced static balance.

Furthermore, it is recommended that balance training target the specific deficits observed, whether in static or dynamic balance. Future research should examine the efficacy of these learning approaches in older adults across a wider age range and investigate the underlying mechanisms in more detail. Comparative studies evaluating the combined effects of cognitive and physical interventions on balance and other aspects of motor function in older adults would also be valuable. Overall, this study highlights the potential of implicit learning as a complement to traditional balance training for enhancing postural control in the aging population.

Conflict of interest
The authors declared no conflicts of interest.

Authors' contributions
All authors contributed to the original idea, study design.

Ethical considerations
The authors have completely considered ethical issues, including informed consent, plagiarism, data fabrication, misconduct, and/or falsification, double publication and/or redundancy, submission, etc. The study was conducted in accordance with the Declaration of Helsinki, and approved by the Institutional Review Board (or Ethics Committee) of Department of Physical Education, Faculty of Educational Sciences and Psychology Shiraz university (protocol code SPE/ .IR.US.PSYEDU.REC.1401.001 and date 2023-03-01 of approval). Informed consent was obtained from all subjects involved in the study.

Data availability
The dataset generated and analyzed during the current study is available from the corresponding author on reasonable request.

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