ORIGINAL RESEARCH

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# Comparison of the Effects of Vestibular-Based and Calisthenics-Based Exercises on Cognitive Function and Dual Task in Ambulatory Older Adults Living in Nursing Home: A Randomized Controlled Trial

**Mert Volkan Şahin[1], Uğur Cavlak[2]**

[1]*Zeytinburnu Semiha Şakir Nursing Home, İstanbul, Türkiye*
[2]*Biruni University Faculty of Health Sciences, Department of Physiotherapy and Rehabilitation, İstanbul, Türkiye*

## Abstract

**Objective:** This study aimed to assess the effects of vestibular-based exercises (VBEs) and calisthenics-based exercises (CBEs) on cognitive function and dual-task performance in older adults.

**Materials and Methods:** Thirty older adults were divided into two groups: VBE (n=15) and CBE (n=15). Standardized Mini Mental State Test (SMMST) and two dual-task tests were used to evaluate participants: (1) participants were asked to count from 1 to 20 while walking Dual Task 1 (DT 1) , and (2) participants used their foot to track a set of stimulators placed on the ground Dual Task 2 (DT 2). Participants took Part in an 8-week exercise program (3 days per week).

**Results:** Both groups showed significant improvements ($p<0.05$), with no differences in DT 1 scores ($p>0.05$). The VBE group had greater improvements in SMMST scores ($p<0.05$), while the CBE group showed more significant gains in DT 2 ($p<0.05$). Both VBEs and CBEs were effective in enhancing cognitive function, with VBEs outperforming CBEs in enhancing cognitive function, and CBEs excelling in dual-task performance.

**Conclusion:** Both types of exercises can be easily integrated into geriatric rehabilitation programs to improve cognitive function and dual-task performance of older people.

**Keywords:** Aging, cognitive disorders, dual task, exercise, geriatric physical therapy, healthy aging

## Introduction

The aging process is a natural one in which decline is observed in sensory, motor, coordination, and cognitive functions. According to the World Health Organization (WHO), old age is defined as "the gradual decrease in the ability to adapt to environmental factors". According to the WHO, healthy ageing involves enhancing and preserving the functional abilities that support well-being in later life. The WHO outlines various stages of aging, typically categorized into specific age groups. Although there are different ways to classify elderly adults, a common classification is as follows: (1) elderly adults between the ages of 65 and 74 years as youngest-old, (2) those between ages 75 and 84 years as middle-old, (3) those aged over as oldest-old (1,2). These classifications are used in public health and demographic studies to address the needs of different age populations (3). During old age, changes begin to occur in various functions of the body. With aging, the weakening of muscle strength, a decrease in pulmonary functions, disorders in the cardiovascular system, loss of postural control, and balance can be observed. Neurological changes may also occur. In addition to slowing down in motor responses, cognitive disorders such as decreased sensory stimulation, losses in memory and learning, and disorganization of thought may also occur. The resulting

**Address for Correspondence:** Uğur Cavlak, Biruni University Faculty of Health Sciences, Department of Physiotherapy and Rehabilitation, İstanbul, Türkiye
**E-mail:** ucavlak@biruni.edu.tr **ORCID:** orcid.org/0000-0002-5290-9107
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cognitive deficiencies can sometimes cause balance disorders (4,5,6). Changes in structure, function, and blood flow in an aging brain are other factors that lead to cognitive impairments (7). With aging, decline in physical and cognitive functions is inevitable. Individually planned exercise programs, regardless of age and health status, improve physical fitness and improve cognitive functions along with neurochemical changes in the central nervous system, by increasing cerebral blood flow. In addition to weight-bearing exercises, calisthenics exercises are also recommended for elderly individuals, including walking, running, cycling, yoga, swimming, and aquatic exercises (1). Exercise improves individuals both physiologically and psychologically. It ensures the continuation of independence in the elderly. It is stated that exercise prevents the negative effects of aging on health and contributes to a person's independent living (8). Studies have shown that physical activity has an effect on cognitive functions in elderly individuals. In a study conducted by Stuck et al. (9), it was reported that cognitive dysfunctions are very important among the factors that cause a decrease in functional activity level. A study reported that the physical activity levels of elderly people with poor cognitive functions were more limited (10,11). Exercises are at the forefront in the rehabilitation of vestibular problems. Since the 1940s, exercises have been used for the treatment of complaints of decreased balance and dizziness in peripheral vestibular disorders (12). Vestibular rehabilitation is generally used to improve posture, walking stability, and balance, to ensure independence in walking and daily living activities, to improve the individual's visual ability during head movements, to reduce the patient's social isolation and increase social participation, and to increase neuromuscular control (12,13). It has been observed that aerobic exercises are more effective in improving cognitive functions in elderly female individuals with mild cognitive impairment than stretching exercises (14). Studies conducted by various researchers have reported that activities such as aerobic exercises, strength training, and balance exercises improve cognitive functions (15,16). In a meta-analysis examining the effect of aerobic exercise on cognitive functions, it was observed that aerobic exercises improved cognitive functions in elderly individuals (17). Sertel et al. (5), in their study reported that deterioration in cognitive functions and increased depression level negatively affected balance. A systematic review indicated that while physical activity is generally associated with cognitive benefits, findings from randomized controlled trials remain inconsistent (18). Up-to-date information is needed to investigate the effects of new training methods developed in recent years on cognitive function. When the literature was examined, no research was found comparing the effects of vestibular-based exercises (VBEs) and calisthenics-based exercises (CBEs). Therefore, we decided to plan a study examining this issue. The main purpose of our study was to examine the effects of VBEs and CBEs on cognitive level and dual-task activities in elderly individuals, and to compare them in terms of effectiveness. This study has two main goals. First, it aims to evaluate the impact of VBEs and CBEs on cognitive function. Second, it seeks to describe the effects of these exercises on dual-task performance in older adults.

Two main hypotheses were formulated for this study:

**Hypothesis 1 ($H_1$):** Two different exercise programs (VBE and CBE) can improve cognitive function and dual task performance in older people.

**Hypothesis 2 ($H_2$):** These two exercise programs have advantages over each other in improving cognitive function and dual-task performance in older adults.

## Material and Methods

### Study Design and Participants

Ethical approval was obtained from the Research Ethics Commission at Biruni University, İstanbul, Türkiye (decision number: 2022/76-14, date: 02.12.2022) and all the participants provided a written informed consent. The study began with 30 ambulatory older adults (aged 65-85) (Figure 1); all of them were enrolled participants in the Zeytinburnu Semiha Şakir Nursing Home, İstanbul, Türkiye. This study was conducted in the period of 7 months (December 2022-June 2023).

Participants eligible for this study were men and women between the ages of 65 and 85 residing in a nursing home who were capable of independently managing daily activities, including using a cane or elbow crutches. Additionally, participants had to volunteer to take part in the study. The exclusion criteria included individuals with any orthopedic, neurological, or psychiatric conditions that would prevent them from participating in the assessment or exercise program of the study. Fifteen individuals were excluded from the study due to medical conditions-most frequently untreated hypertension and balance issues-while an additional 17 declined to participate. (Figure 1).

Based on the inclusion criteria and medical assessment, a total of 30 participants aged 65-85 years were randomly assigned to one of two groups: VBEs group (n=15) performing VBEs (8 weeks, 3 times per week) or CBEs group (n=15) performing CBEs (n=15) (8 weeks, 3 times per week). Participants in both groups were divided into smaller groups (each group consisted of 5 older adults) when performing the exercises.

### Type of Randomization

Randomization was performed with a 1:1 distribution using the "simple random method", which aims to generate a 1:1 distribution over a given sample size using a random selection process in which each individual has an equal chance of being selected. We preferred this method because of its simplicity and

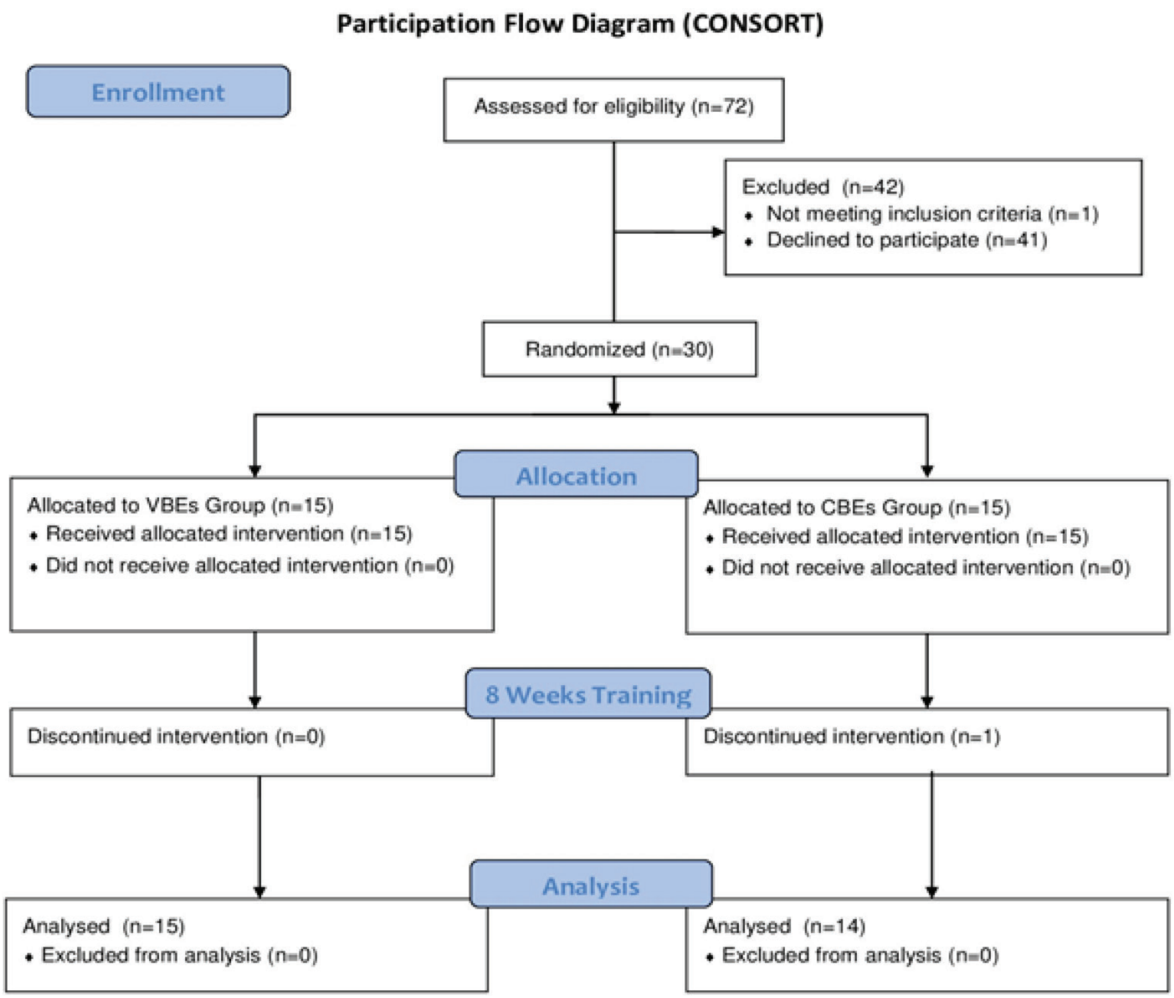


**Figure 1.** Flowchart of the study design

*VBE: Vestibular-based exercises, CBEs: Calisthenics-based exercises*

applicability. A total of 30 participants began engaging in the exercise regimens, but the full training cycle was completed by 15 participants from the VBEs group and 14 participants from the CBEs group (one participant could not complete the training program) (Figure 1).

Inclusion criteria were female and male participants between 65 and 85 years of age living in the senior home where the study was conducted, able to walk independently with or without a stick, and free of orthopedic, neurological, disease, or psychiatric.

## Outcome Measures

Qualification was conducted by a physiotherapist (PT) and included a medical-history interview and analysis of medical records, after which potential participants were excluded if required on this basis. Demographic data belonging to the participants were recorded by the researcher, who is a PT working in the senior home (MVS). The socio-demographic characteristics of all participants such as age, gender, height, body weight, Body Mass Index (BMI) scores, education level, and length of stay in the nursing home were recorded on a structured form by the authors for this study. After that, the participants completed the The Standardized Mini-Mental Status Examinitaion (SMMSE) in a quiet and well-lit room under the supervision of the PT one by one. The other outcome measurements were performed under the same PT in the following order in the same room condition mentioned earlier: Dual Task 1 (DT 1) and Dual Task 2 (DT 2). All tests were conducted twice, before commencing the exercise program, (before the first week of the VBEs or CBEs programs) and immediately after (9$^{th}$ week of the study). The following parameters were analyzed.

## The Standardized Mini-Mental Status Examination

This test, the most commonly used by clinicians and researchers, was originally developed by Folstein to assess mental status (19). A standardized version was later developed (20). The maximum score is 30, with scores of 24 and below indicating evaluation within the dementia framework. The Turkish adaptation was conducted (21), and the revised version was studied by Keskinoglu et al. (22). The cut-off point for the revised version is 22-23 for the educated elderly, whereas the cut-off point for the uneducated elderly is 18-19. This test assesses cognitive functions across five sections: orientation, registration, attention and calculation, recall, and language. The maximum score is 30, with scores of 24 and below indicating that evaluation should consider the possibility of dementia.

### Dual Task 1 (Motor + Cognitive) Test: A 10-Meter Walking

The 10-m walk test with the added complexity of a cognitive task is often referred to as "dual-task walking" or "cognitive-motor interference" tasks. This test is commonly used to assess both physical performance (walking speed) and cognitive function (such as attention and working memory) simultaneously. The participant's walking speed in the 10-m area is assessed using a stopwatch. The participant is instructed to walk within the designated area, with timing starting when their foot touches the starting line and stopping when they cross the finish line. The measurement is taken, and the result is recorded in meters per second (m/s). The participant was asked to count from 1 to 20 while walking (23,24,25).

### Dual Task 2 (Cognitive+ Motor) Test: The Trail Making Test-Part B

Originally developed by psychologists in the United States Army, the Trail Making Test - Part B is a commonly used tool in neuropsychological assessment. The test demands both visual-spatial processing and motor coordination. It is divided into two sections: Part A and Part B. Part A measures processing speed through tasks involving visual scanning, whereas Part B assesses cognitive flexibility and the ability to alternate between sequences. Due to its higher demands on visual-spatial and executive functioning, Part B is more complex and typically takes longer to complete than Part A (26,27). In addition, Part B is more difficult than Part A because it requires more motor speed, agility, and attention. That is why we chose Part B of the test for this study. Participants tracked a set of stimulators placed on the ground with their foot. Participants were first allowed a trial, then the test began.

## Training

Exercise sessions (~45 minutes each) were carried out in groups of 5 participants three times a week for 8 weeks. Each exercise session was carried out three days a week in the gymnasium of the nursing home where the participants lived, accompanied by music and under the supervision of a PT. In the VBEs group, participants engaged in 12 easy-to-perform non-strenuous exercises performed in low body positions, which involved participants rotating their eyes, heads, and bodies in the sagittal, transverse, and frontal planes (Appendix A). The CBEs participants performed 12 easy-to-perform exercises (Appendix B). Training sessions were performed to music as a small group consisting of 5 persons supervised by a PT, who is working in the senior home where the study was conducted: warm-up (5 minute), exercise training (35 minute), and cool-down (5 minute). During the 8-week exercise program, we did not use any strengthening exercise protocol for progression because we did not aim to increase muscle strength. As the exercise program progressed, the number of repetitions was gradually increased ($1^{st}$-$2^{nd}$ weeks: 6x; $3^{rd}$-$5^{th}$ weeks: 8x; $7^{th}$-$8^{th}$ weeks: 12x). The 8-week exercise programs consisted of three sets with a 2-minute break in each session. Sessions began with a 5-minute warm-up followed by the main part of the training program (35 minutes), in which a series of VBEs or CBEs, and 5-minute cool down exercises were performed on a stable floor in a well-lit gym. Each session consists of three sets with 2 minutes rest between sets, completed in 45 minutes.

### Statistical Analysis

The distribution of the data was examined with the Shapiro-Wilk test. An Independent Samples t-test was used to compare two normally distributed independent groups. The Pearson chi-square or the Fisher's exact chi-square tests were applied to determine the homogeneity of categorical variables between two groups. The Dependent Samples t-test was applied for comparisons of two dependent groups assuming a normal distribution, and the Wilcoxon test was applied for comparisons of two dependent groups not assuming a normal distribution. The repeated measures ANOVA test was applied to evaluate the changes before and after between groups. For variables with a normal distribution, descriptive statistics were presented as mean ± standard deviation (SD), whereas non-normally distributed variables were reported using median and range (minimum-maximum). All statistical analyses were performed using IBM SPSS Statistics version 26.0, with a significance threshold set at $\alpha=0.05$. This study was completed with a total of 29 participants in the two groups. Post-hoc analysis was performed. Based on the post-hoc analysis, a sample size of 29 gives 90% power to detect a difference of +1.9 between the null hypothesis mean of 22.4 and the alternative hypothesis mean of 24.3 with a known SD of 2.5 and a significance level (alpha) of 0.05 using a two-sided one-sample t-test (28,29).

## Results

Of the 30 ambulatory older adults who have mostly graduated from primary school, 21 (70%) of the participants are men and 9 (30%) are women. Table 1 shows the demographic distribution of the groups. The participants in the two groups were homogeneous except for the gender distribution ($p\geq0.05$). The average age of the participants is about 75 years. This means that the participants in the study ranged from the youngest age group to the middle-aged group, according to the WHO.

A comparison of the descriptive statistics of the results of the Standardized Mini Mental Status Test (SMMT), DT 1, and DT 2 tests is shown in Table 2. This table shows us that both groups (VBEs and CBEs) showed significant improvement in terms of the outcome measurements [Standardized Mini Mental State test (SMMST), DT 1, DT 2] used to evaluate the participants ($p \leq 0.05$). These results supported the idea that $H_1$ was proven.

Table 3 shows the comparison of the test results of the groups before and after the 8-week training program. There were significant differences among the four outcome measurements ($p \leq 0.05$) except for DT 1 ($p \geq 0.05$). However, for SMMT, the change was significantly more extensive in the VBEs group than in the CBEs group. The changes in DT 2 test results were significantly higher in the CBEs group than in the VBEs group ($p \leq 0.05$). These results supported the idea that $H_2$, which stated that the two exercise regimes have advantages over each other, was proven.

## Discussion

The results of this study, which was conducted to determine and compare the effects of two different vestibular and calisthenics-based physical exercise training (VBEs vs. CBEs) on cognitive function and dual task performance in elderly individuals, showed that improvements in cognitive function and dual task performance can be achieved with VBEs and CBEs without the use of expensive technological systems. When the results of VBEs and CBEs were compared with each other, VBEs, which included more complex figures, showed superiority over CBEs in improving mental function according to the SMMST score. On the other hand, CBEs showed enhanced performance in dual-task involving cognitive and motor tasks.

Cognitive problems have been the subject of numerous studies so far. These studies aimed to devise and implement programs to help older adults improve their cognitive function and to prevent cognitive decline. The researchers are particularly interested in the positive effects of physical exercise, well known to health providers. Similarly, PTs working with older adults with or without physical problems have tried to find optimal training methods to improve their physical functioning. However, the aging process is not only a natural process affecting the physical functioning of the elderly, but also a process in which decline is observed in cognitive functions.

As elderly people who are living in a senior home, are frequently resistant to the idea of continuing to exercise and using complicated technologic systems to be more active, a set of simple exercises aimed at improving the main components of health, including the physical and cognitive components should be designed. Based on this idea, we planned this study, which covers exercises that can be done easily by elderly people living in nursing homes and can be integrated into daily physiotherapy programs.

There are many tests or tools available to assess cognitive function in older people. The SMMSE and Trail Making test parts A and B used in this study are widely used. They have also been included in studies with a high degree of reliability, such as meta-analyses and systematic reviews. da Silva et al. (30) also used studies that included the SSME and Trail Making test Parts A and B in the assessment of cognitive function in their

**Table 1. Descriptive parameters and statistical tests by groups**

| Variable | VBEs | CBEs | p |
|---|---|---|---|
| **Gender** | **n (%)** | **n (%)** | |
| Male/female | 10 (66.7)/5 (33.3) | 10 (73.3)/4 (26.7) | 1[a] |
| **Education level** | | | |
| Literate | 1 (6.7%) | 3 (20%) | 0.359[a] |
| Primary school | 6 (40%) | 9 (60%) | |
| Middle school | 3 (20%) | 2 (13.3%) | |
| High school | 4 (26.7%) | 1 (6.7%) | |
| University level | 1 (6.7%) | - | |
| **Variable** | **Mean ± SD** | **Mean ± SD** | |
| Age, year | 74.67±5.87 | 75.13±4.70 | 0.812[b] |
| Height, cm | 167±7.84 | 169.07±8 | 0.481[b] |
| Weight, kg | 77.80±9.17 | 80.47±11.17 | 0.481[b] |
| BMI, kg/m² | 27.90±2.99 | 28.19±4.02 | 0.827[b] |
| Length of staying in nursing home, year | 6.73±2.39 | 6±3.04 | 0.650[b] |

VBE: Vestibular-based exercises, CBE: Calisthenics-based exercises, [a]: Chi-square test, [b]: Independent Samples t-test, BMI: Body Mass Index, SD: Standard deviation

**Table 2. Comparison the results before and after the 8-week training program belonging to the VBEs and CBEs groups**

| Group | Before training | After training | p |
|---|---|---|---|
| **VBEs (n=15)** | **Mean ± SD** | **Mean ± SD** | |
| SMMST | 23.13±2.44 | 25.27±2.37 | **0.001**[c] |
| DT 1 | 15.19±4.19 | 12.88±4.01 | **0.001**[c] |
| DT 2 | 208.60±58.48 | 196.07±60.31 | **0.001**[c] |
| CBEs (n=14) | **Mean ± SD** | **Mean ± SD** | |
| SMMST | 21.47±2.10 | 23.21±2.25 | **0.001**[c] |
| DT 1 | 18.20±4.37 | 15.84±4.37 | **0.001**[d] |
| DT 2 | 255.33±43.72 | 238.93±43.97 | **0.001**[d] |

VBE: Vestibular-based exercises, CBE: Calisthenics-based exercises, SMMT: Standardized Mini Mental Status Test, DT 1: Dual Task 1, DT 2: Dual Task 2, [c]: Depended Samples t-test, [d]: Wilcoxon test, SMMST: Standardized Mini Mental State Test

**Table 3. Comparison the results before and after the 8-week training program by the VBEs and CBEs groups**

| Variable | VBEs[1] Mean ± SD | CBEs[2] Mean ± SD | Mean difference (1-2) | p[e] |
|---|---|---|---|---|
| **SMMST** | | | | |
| Before training | 23.13±2.44 | 21.47±2.10 | 1.771 | **0.044** |
| After training | 25.27±2.37 | 23.21±2.25 | | |
| **DT 1** | | | | |
| Before training | 15.19±4.19 | 18.20±4.37 | 2.776 | 0.084 |
| After training | 12.88±4.01 | 15.84±4.37 | | |
| **DT 2** | | | | |
| Before training | 208.60±58.48 | 255.33±43.72 | -43.131 | **0.035** |
| After training | 196.07±60.31 | 238.93±43.97 | | |

VBE: Vestibular-based exercises, CBE: Calisthenics-based exercises, SMMT: Standardized Mini Mental Status Test, DT 1: Dual Task 1, DT 2: Dual Task 2, [e]: Repeated Measures ANOVA, SMMST: Standardized Mini Mental State Test

systematic review. In the meta-analysis conducted by Northey et al. (31), it was observed that these tests used for cognitive assessment showed improvements in cognitive function. Recently, motor-motor, motor-cognitive, or cognitive-cognitive dual-task tests have been widely used in geriatric assessment programs. Assessing the dual-task abilities of older people and training them with dual-task activities may increase the likelihood of success of functional exercise training. There are many studies in the literature on this topic. In our study, the 10-meter walk test (motor + cognitive) and Trail Making test Part B (cognitive + motor) were also used, performing a cognitive task. The authors' selection of such widely used tests is one of the strengths of this study.

The WHO Physical Activity Sedentary Behaviours Guide, published in 2020, states that regular physical activity in adults aged 65 and over has beneficial effects such as reduced all-cause mortality and improvements in many systems, including cognitive health.

In the related literature (18,32), there are also many studies, including aerobics, strength training, resistance training, yoga, clinical pilates, Tai Chi, which confirm that many exercises improve physical and cognitive function, and brain structure in older people. Siqueira et al. (33) reported that square-step exercises, which they used differently from the exercise methods we used in our study, improved both physical and cognitive function in older people. A review examining the impact of aerobic exercise, resistance training, and Tai Chi on cognitive function in older adults without diagnosed cognitive impairment found notable improvements. Specifically, resistance training led to greater gains in reasoning abilities compared to stretching or toning exercises, while Tai Chi was associated with enhanced attention and processing speed relative to inactive control groups (32). Zhang et al. (34) reported that engaging in muscle-strengthening activities was associated with cognitive health in middle-aged and older adults, independent of aerobic exercise. However, most of these studies used sophisticated techniques and expensive equipment. This study is important because it shows that these simple and cost-free exercises can also be used in the daily care of ambulatory older people living in senior homes to improve their cognitive and physical function. That is the strength of this study.

The core of vestibular rehabilitation such as the Cawthorne-Cooksey exercises (35,36,37) involves exercises and interventions that stimulate and challenge the vestibular system to promote neural plasticity and adaptation. These exercises are carefully designed to gradually desensitize patients to movement and balance challenges, improve gaze stability, and enhance postural control. The ultimate goal is to restore optimal function and improve the patient's overall quality of life. Developed in the 1940s by Cawthorne and Cooksey (35), the exercises are widely used as an effective vestibular rehabilitation intervention. In this study, we have selected some simple exercises based on the Cawthorne-Cooksey exercises, which are commonly used to improve posture, gait stability and balance, to ensure independence in walking and activities of daily living, to improve the individual's visual ability during head movements, to reduce social isolation while increasing social participation, and to improve neuromuscular control.

There are many studies in the literature reporting the beneficial effects of vestibular stimulation exercises, such as those described in a study by Wiszomirska et al. (38). These exercises should be part of interventions to improve balance in older adults. The structured VBEs used in this study involve simple exercises that stimulate the vestibular organ. This set of exercises does not require a lot of energy or time; moreover, it stimulates cognitive function. Participants who performed VBEs showed positive changes to the SMMSE compared to participants doing CBEs. We believe this is due to the complex movements of VBEs, which include posture, gait stability and balance, independence in walking and activities of daily living, visual ability during head movements, and neuromuscular control. These findings promised new ideas to integrate VBEs into a physiotherapy program, that actuates the vestibular organs by means of movements of the head and body in different planes. To our knowledge, there are no studies reporting the effect of VBEs on cognitive function in the relevant literature. Therefore, we could not compare the results obtained from this study with the literature.

Calisthenics, a form of exercise that emphasizes bodyweight movements, has been shown to significantly improve physical functioning in ambulatory older adults. Research indicates that engaging in regular calisthenics activities enhances balance, strength, and overall mobility, which are critical for maintaining independence in this population (39). A study by Kearney et al. (40) found that older adults who participated in a structured calisthenics program exhibited improvements in functional fitness measures, including increased lower body strength and balance, leading to a reduced risk of falls. Additionally, the progressive nature of calisthenics allows older individuals to tailor their workouts according to their individual capabilities, promoting adherence and sustained physical activity (41). Overall, integrating calisthenics into the exercise regimens of ambulatory older adults can contribute positively to their physical functioning and quality of life. Different from the related literature, we aimed to show the effects of CBEs performed for 8 weeks on the cognitive function and dual task of the elderly. As predicted in our hypothesis $H_1$, CBEs improved the cognitive (SSMET score) and dual tasks (10-metre walk test, and Trail Making test Part B) scores of the elderly. In addition, CBEs were more effective than VBEs in improving dual task cognitive + motor scores (the Trail Making test Part B) in the elderly. Participants who did CBEs for 8 weeks improved their SSME score, but not as much as those who did VBEs. That is, participants who performed VBE showed superior improvement in terms of progression in the SSME score. However, participants who performed CBEs showed greater improvements in dual task-cognitive + motor test scores based on the Trail Making test Part B. These results support our hypothesis $H_2$. Although the CBEs, which are frequently integrated into exercise programs, are known to improve physical function, their effect on cognitive function has not been investigated. This is also true for the VBES. The results of this study can be considered instructive in terms of showing that both exercise programs can improve cognitive functions in the elderly.

### Study Limitations

The most powerful aspect of this study is that there were no significant differences in age, height, weight, or BMI between the groups of participants who completed the two training programs. This made the comparison between the two groups stronger. In addition, the two exercise programs, simple and cost-free exercises undertaken by the participants, could show improvements in both cognitive function and dual-task performance in older adults, and the hypotheses were supported by the results obtained. However, this study has some limitations: (1) we had to conduct this study in only one nursing home with 72 older adults; so we could not ensure gender equality. Therefore, our results may not be generalizable to the whole elderly population due to the relatively small number of participants and the fact that we couldn't show the gender differences; (2) Another limitation of this study is that the exercise training program was not applied for a longer duration, and its long-term effects could not be evaluated. These limit the generalizability of the results.

## Conclusion

The results of this study indicate that there is a need for much more research with more participants to explore the effects of VBES and CBE on cognitive function and dual tasking in older adults and to compare male and female older adults. Practitioners working in this field should be aware of the benefits of developing and implementing these types of exercises, which are easy for older adults to incorporate into their daily routines in order to promote a healthier lifestyle and improve health-related quality of life.

## Ethics

**Ethics Committee Approval:** Ethical approval was obtained from the Research Ethics Commission at Biruni University, İstanbul, Türkiye (decision number: 2022/76-14, date: 02.12.2022)

**Informed Consent:** All the participants provided a written informed consent.

## Footnotes

### Authorship Contributions

Concept: M.V.Ş., U.C., Design: M.V.Ş., U.C., Data Collection or Processing: M.V.Ş., U.C., Analysis or Interpretation: M.V.Ş., U.C., Literature Search: M.V.Ş., U.C., Writing: M.V.Ş., U.C.

**Conflict of Interest:** No conflict of interest was declared by the authors.

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| Appendix A: Vestibular-based exercises (45 minutes – three sets with 2 minutes rest between each set) |
|---|
| **Warm up exercises (5 minutes)**<br>• Diaphragmatic breathing combined with raising and lifting both shoulders<br>• Diaphragmatic breathing with trunk rotation while holding arms in a 90-degree position and elbows extended<br>• Deep breathing while lifting fingertips upward<br>• 2 minutes of free walking |
| **The training program (35 minutes)** |
| Tracking the finger with the eye (right and left) |
| Looking up with the eyes while keeping the head still |
| Looking down with the eyes while keeping the head still |
| Neck flexion and extension |
| Neck rotation to both sides (right and left) |
| Picking up an object from the ground in a sitting position |
| Repeating the 4th and 5th neck movements in the sitting position |
| Repeating the 1st, 2nd, and 3rd eye movements in the sitting position |
| Transferring objects from hand to hand under the knees while standing |
| Getting up from the sitting position and sitting again (5 repetitions with eyes open, 5 repetitions with eyes closed) |
| Throwing and catching a tennis ball above eye level |
| Standing and turning to the right and left |
| **Cool down exercises (5 minutes)**<br>• Diaphragmatic breathing combined with raising and lifting both shoulders<br>• Diaphragmatic breathing with trunk rotation while holding arms in a 90-degree position and elbows extended<br>• Deep breathing while lifting fingertips upward<br>• 2 minutes of free walking |

| Appendix B: Calisthenics exercises (45 minutes – three sets with 2 minutes rest between each set) |
|---|
| **Warm up exercises (5 minutes)**<br>• Diaphragmatic breathing combined with raising and lifting both shoulder<br>• Diaphragmatic breathing with trunk rotation while holding arms in a 90-degree position and elbows extended<br>• Deep breathing while lifting fingertips upward<br>• 2 minutes of free walking |
| **The training program (35 minutes)** |
| Outward circling with the arm (unilateral-left) in standing |
| Outward circling with the arm (unilateral-right) in standing |
| Outward circling with the arms (bilateral) in standing |
| Flexion and extension of both shoulders in standing |
| Trunk rotation to the right and left with arms at shoulder level flexed at 90 degrees with extended elbows in standing |
| Elbows flexion and in extension at shoulder level at 90 degree flexion in standing |
| Elbow flexion and extension with arms at shoulder level at 90 degrees abduction in standing |
| Half squat |
| Marching with left & right steps & side stepping with right and left leg |
| Standing tip-toes exercise |
| Unilateral hip extension (keeping the knee in extension) (right and left) |
| Sit to stand exercise |
| **Cool down exercises (5 minutes)**<br>• Diaphragmatic breathing combined with raising and lifting both shoulders<br>• Diaphragmatic breathing with trunk rotation while holding arms in a 90-degree position and elbows extended<br>• Deep breathing while lifting fingertips upward<br>• 2 minutes of free walking |