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ORIGINAL ARTICLE

The effect of single-task and dual-task balance exercise programs on balance performance in adults with osteoporosis: a randomized controlled preliminary trial

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Abstract

Summary Osteoporosis is a serious disease characterized by muscle weakness in the lower extremities, shortened length of trunk, and increased dorsal kyphosis leading to poor balance performance. Although balance impairment increases in adults with osteoporosis, falls and fall-related injuries have been shown to occur mainly during the dual-task performance. Several studies have shown that dual-task performance was improved with specific repetitive dual-task exercises.

Introduction The aims of this study were to compare the effect of single- and dual-task balance exercise programs on static balance, dynamic balance, and activity-specific balance confidence in adults with osteoporosis and to assess the effectiveness of dual-task balance training on gait speed under dual-task conditions.

Methods Older adults ($N = 42$) (age range, 45–88 years) with osteoporosis were randomly assigned into two groups. Single-task balance training group was given single-task balance exercises for 4 weeks, whereas dual-task balance training group received dual-task balance exercises. Participants received 45-min individualized training session, three times a week. Static balance was evaluated by one-leg stance (OLS) and a kinesthetic ability trainer (KAT) device. Dynamic balance was measured by the Berg Balance Scale (BBS), Time Up and Go (TUG) test, and gait speed. Self-confidence was assessed with the Activities-specific Balance Confidence (ABC-6) scale. Assessments were performed at baseline and after the 4-week program.

Results At the end of the treatment periods, KAT score, BBS score, time in OLS and TUG, gait speeds under single- and dual-task conditions, and ABC-6 scale scores improved significantly in all patients ($p < 0.05$). However, BBS and gait speeds under single- and dual-task conditions showed significantly greater improvement in the dual-task balance training group than in the single-task balance training group ($p < 0.05$). ABC-6 scale scores improved more in the single-task balance training group than in the dual-task balance training group ($p < 0.05$).

Conclusions A 4-week single- and dual-task balance exercise programs are effective in improving static balance, dynamic balance, and balance confidence during daily activities in older adults with osteoporosis. However, single- and dual-task gait speeds showed greater improvement following the application of a specific type of dual-task exercise programs.

Clinical trial registration number 24102014–2.

Keywords Balance · Dual-task training · Gait · Osteoporosis · Rehabilitation

Abbreviations

ABC-6	Activities-specific Balance Confidence
BBS	Berg Balance Scale
BMD	Bone mineral density
BMI	Body mass index
KAT	Kinesthetic ability trainer
MMSE	Mini-mental state examination
OLS	One-leg stance
TUG	Time Up and Go

Suppliers' list The software (The Predictive Analytics SoftWare (PASW) Statistics version 18.0) used in the present study was supplied by Ufuk University School of Medicine. G-Power is a free software on the Internet.

a. Sports Kinesthetic Ability Trainer 4000 device; SportKAT.
b. PASW Statistics 18.0; SPSS, Chicago, IL
c. G*Power 3.1.9.2. Available at: http://www.gpower.hhu.de/en.html

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Introduction

Osteoporosis is a serious yet common disease characterized by low bone strength resulting in increased fracture risk [1]. Older adults with osteoporosis often have muscle weakness in the lower extremities, shortened length of trunk, and increased dorsal kyphosis leading to flexed posture [2, 3]. Such postural disorders negatively affect standing, postural balance, and gait performance. The poor balance and increased fear of falling may lead to the avoidance of daily activity, decreased physical function, and increased risk of falling [4, 5]. Falls and fall-related injuries among adults with osteoporosis are associated with high morbidity and mortality and can necessitate high-cost medical intervention [6].

Although balance impairment increases in adults with osteoporosis, falls and fall-related injuries have been shown to occur mainly during the performance of simultaneous daily activities [7, 8]. Several studies in young and older adults have shown that motor tasks are affected by the addition of a simultaneous cognitive task. For example, walking while talking on the phone or remembering a name influences standing posture control and gait pattern resulting in a slower walking speed [9–11]. For this reason, the improvement of standing balance and gait speed under dual task conditions and increase in the activity-specific balance confidence are priorities.

Several experimental studies have aimed at improving dual-task postural control and gait performance in healthy older adults. It has been shown that the ability to perform two tasks at the same time increases with specific repetitive dual-task exercises, and that dual-task performance is influenced by the types of exercises and their difficulty [12–14]. A study investigating the effects of single-task versus dual-task training on balance performance in older adults found that the dual-task training group demonstrated greater improvement in gait speed under dual-task conditions compared to the single-task training group [15]. A recent review reported that dual-task training is more effective than single-task training for improving dual-task standing balance control, whereas both dual-task and single-task training improved dual task gait performance [16]. However, in the literature, there are no studies that investigate the effects of dual-task training on balance and activity-specific balance confidence in adults with osteoporosis.

There are several physiotherapy programs designed to prevent reduced balance control in patients with osteoporosis. The majority of these programs are based on exercises to increase muscle strength, joint range of motion, endurance, flexibility, and aerobic capacity [17, 18]. However, we know of only one study that has focused on the effects of dual-task balance exercises on dual-task performance in patients with osteoporosis. Halvarrson et al. investigated the effects of specific and progressive balance training with dual and multi-task exercises on fall-related self-efficacy, fear of falling, preferred walking speed with and without a cognitive dual task, fast walking, and balance performance in older adults with osteoporosis. They reported that intervention groups significantly improved their fall-related self-efficacy, balance performance, fast walking speed, and walking speed during dual-task conditions as compared to the controls [19].

The aim of our study was to compare the effect of single-task and dual-task balance exercise programs on static balance, dynamic balance, and activity-specific balance confidence in adults with osteoporosis. In addition, we aimed to assess the effectiveness of dual-task balance training on gait speed under dual-task conditions. Our working hypothesis was that a dual-task balance exercise program would be more effective at improving balance performance under dual-task conditions than single-task balance training in these patients.

Methods

A total of 51 patients with osteoporosis were evaluated between January 2012 and March 2014. Patients with osteoporosis were determined according to the World Health Organization osteoporosis diagnostic criteria [20]. Participants with Folstein mini-mental state examination (MMSE) scores [21] of less than 24 and Berg Balance Scale of more than 52 were excluded. Other exclusion criteria included severe orthopedic conditions, eye and internal ear pathologies that could lead to imbalance, vitamin B12 or folate deficiencies, the usage of any drugs that may affect balance, diabetes mellitus, neurologic diseases, rheumatoid diseases, advanced cardiovascular or lung pathologies, and uncontrolled hypertension or hypotension.

Eligible patients were randomized into two groups by a researcher unaware of the treatment procedures. The enrollment and allocation process is shown in Fig. 1.

Of the initial 51 participants, 3 did not meet the inclusion criteria, 1 refused to participate, and 2 patients in the single-task balance training group and 3 patients in the dual-task balance training group dropped out of the study. Single-task training group consisted of 20 patients given single-task balance training and dual-task training group of 22 patients receiving dual-task balance training. Patients were assessed at baseline and after the 4-week exercise program under the same conditions by two experienced physiatrists who were blinded to the groups.

This study was carried out in accordance with the Declaration of Helsinki and was approved by the research committee of the Ufuk University School of Medicine. Written informed consent forms were provided from all participants.

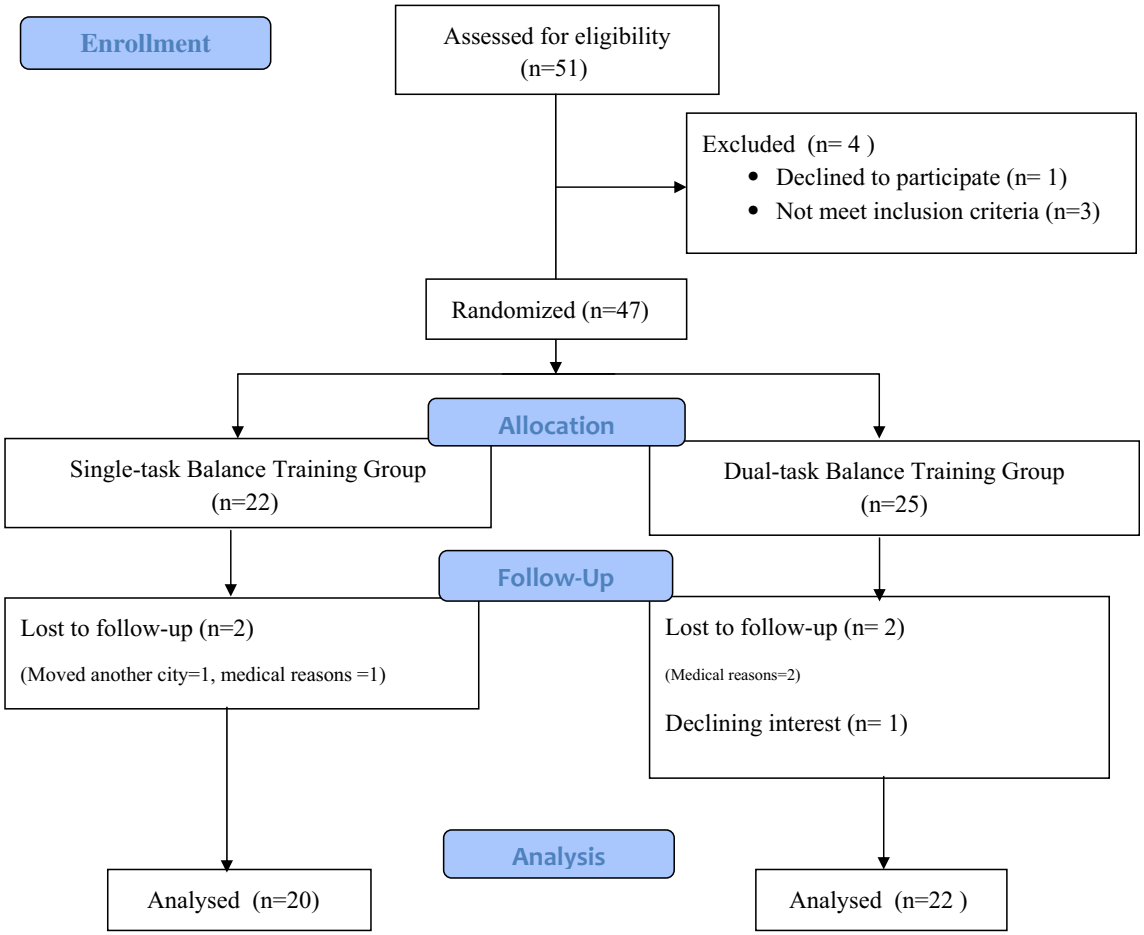

Fig. 1 Flow of participants (allocation and randomization process)

Exercise procedures

Single-task balance exercises

Single-task balance training group patients were given balance exercises under single-task conditions (only balance task). Balance exercises included postures designed to gradually reduce the base of support (2-legged stand, semi-tandem stand, tandem stand, 1-legged stand), dynamic movements to disturb the center of gravity (tandem walk, circle turns), exercises to stress the postural muscle groups (heel or toe stands), and exercises to reduce sensory input (standing with eyes closed) as recommended by the American College of Sports Medicine [22]. Patients received 45-min individualized training session, three times a week for 4 weeks.

Dual-task balance exercises

Dual-task balance training group patients received balance exercises under dual-task conditions (balance task exercises as in single-task training group plus simultaneous cognitive tasks). Cognitive tasks included counting backwards, counting the days of the week, and naming objects that had been described in detail elsewhere. Patients received 45-min individualized training session, three times a week for 4 weeks.

Assessment parameters

Sociodemographic data (age, sex), education levels, marital and working status, and number of falls in the last year were recorded. To establish a fall history, we conducted an interview and we defined a fall as unintentionally coming to rest on the ground, floor, or other levels either with or without an injury [23]. Weight and height were measured and body mass index (BMI) [(W—kg)/H^2—m^2)] was calculated. Bone mineral density T-scores in the lumbar spine, femoral neck, and total femur region were recorded.

Static and dynamic balance and balance confidence evaluation

Static balance performance was assessed with the one-leg stance (OLS) and using the Sports Kinesthetic Ability Trainer (KAT)[a] 4000 device. The OLS is a valid measure and described as a method of quantifying static balance ability

[24, 25]. For the one-leg stance, patients stood alternately on the right or the left one leg for as long as possible with their eyes open and arms on the hips. Three measurements were performed for each leg from the time the foot left the floor until it touched the ground. Measurements were repeated for each leg. The mean of all six measurements was used for analysis. Participants unable to perform the one-leg stand for a minimum of 5 s are considered to be at increased risk for injurious fall [26]. The maximum score for OLS was 30 s [27].

The KAT device has two components including a movable platform and a tilt sensor connected to a computer. During the static balance measurement, patients were asked to cross their arms against their chest and maintain body equilibrium without changing feet on the platform. During the test, patients were instructed to keep the red X symbol located in the center of the computer screen. Each test was performed for 30 s and repeated three times. Increased measurements indicate a poor balance performance [28]. The best of the three scores was accepted as the final score. The reliability of the balance data with the use of the KAT has been described previously [28].

Dynamic balance and mobility was assessed using the Berg Balance Scale (BBS), Time Up and Go (TUG) test, and gait speed. The BBS consists of 14 simple different balance-related tasks testing the ability of the subject's static, dynamic, and functional balance. The degree of success of each task was assessed using a scoring scale between zero (unable) and four (independent). The sum of all scores was calculated out of a maximum of 56 points [29]. The validity and reliability of the Turkish version of the BBS have been proven [30].

The TUG test is a simple test used to measure mobility [31]. Patients were asked to rise from a chair, walk 3 m to the line on the floor at a normal pace, turn around, walk back to the chair, and sit down [32]. While the participants were walking, the researcher observed the patient's postural stability, gait, stride length, and sway. One source suggests that scores of 10 s or less indicate normal mobility, 11–20 s normal limits for frail elderly subjects, and scores of 30 s or more suggest that the person may be prone to falls [32, 33].

Gait speed is a quick, inexpensive, reliable measure of functional capacity [34]. Gait speed was measured under single- and dual-task conditions to evaluate dynamic balance. In the single-task condition, patients walked 10 m at a comfortable speed and the time to reach the middle (6 m) was recorded as single-task gait speed. In the dual-task condition, the patient walked 10 m while answering basic mathematical questions and the time to reach the middle (6 m) was recorded as the dual-task gait speed. In both conditions, the test was repeated two times using a stopwatch and the average value was recorded.

The Activities-specific Balance Confidence (ABC-6) scale is a valid and reliable measure of balance confidence in community-dwelling older adults and was used to determine self-reported balance confidence during the performance of six different daily activities. Each item was rated on a scale ranging between 0 and 100, with a score of zero representing no confidence and 100 complete confidence. Overall score was calculated by adding the item scores and dividing by the total number of items. Higher scores indicated greater self-reported balance confidence [35]. The validity and reliability of the Turkish version of this model have been previously verified [36].

Statistical analysis

The PASW Statistics 18.0 for Windows software[b] program was used for statistical analyses. The Shapiro-Wilk test was used to assess compliance with the normal distribution of the data obtained in the study. The Student's t test was used to measure the variables obtained by the comparison between the two groups and the chi-square and/or Fisher's exact chi-square analyses to measure categorical variables. The paired simple t test was used to evaluate time-dependent measurements of the difference between two samples for each group. Pre-treatment to post-treatment change rates were calculated, and the Student's t test used to compare the changes between groups. Descriptive statistics are given as mean ± standard deviation, and the significance level was set at 0.05.

Power analysis was conducted to estimate the requisite sample size. At the start of the study, we did not find any similar studies in the literature estimating the possible magnitude effect. Previous studies defined a clinically significant difference reduction in BBS as 4 units and a SD of 2.92 in the OP population, and the probability of a type I error of 0.05 and a power of 0.99 resulted in an estimated sample size of 21 for each group (total of 42 patients). Using a G*Power of 3.1.9.2[c] for this calculation, we determined a sample size.

Results

A total of 42 subjects between the ages of 45 and 88 completed the 4-week exercise program. The basal characteristics of both groups were similar in terms of age, BMI, sex, education level, work status, and number of falls ($p > 0.5$) (Table 1). Similarly, there were no differences in bone mineral density (BMD) scores for lumbar spine, femur neck, and total femur T-scores between groups (Table 2). In the first evaluation, there were no statistically significant differences between the groups with respect to the static and dynamic balance parameters and self-reported balance confidence at the baseline measurements ($p > 0.5$) (Table 1).

At the end of the 4-week treatment periods, KAT score, BBS score, time in OLS and TUG, gait speeds under single and dual-task conditions, and ABC-6 scale scores improved significantly in both groups ($p < 0.05$) (Table 3). However, BBS and gait speeds under single- and dual-task conditions

Table 1 The sociodemographic and clinical characteristics of the patients

Variables	Group 1 (*n*:20)	Group 2 (*n*:22)	*p*
Age (years)	68.80 ± 10.12 (45–80)	67.91 ± 12.45 (47–88)	0.89
BMI	26.60 ± 3.66	26.26 ± 9.97	0.79
Sex			0.60
Female	19 (95)	20 (90.9)	
Male	1 (5)	2 (9.1)	
Education level			0.15
Primary	0 (0)	1 (4.5)	
Middle high	17 (85)	16 (72.7)	
University	3 (15)	5 (22.7)	
Work status			1
Unemployed	14 (70)	14 (63.6)	
Working	2 (10)	3 (13.6)	
Retired	4 (20)	5 (22.7)	
Number of falls	0.65 ± 0.74	0.63 ± 0.90	0.95
KAT	353.6 ± 117.95	315.0 ± 119.89	0.30
OLS	9.95 ± 4.37	10.63 ± 4.22	0.60
BBS	48.80 ± 1.85	49.18 ± 1.86	0.51
TUG	12.7 ± 2.29	12.36 ± 2.01	0.61
Single-task gait speed	1.12 ± 0.12	1.15 ± 0.10	0.41
Dual-task gait speed	1.03 ± 0.11	1.04 ± 0.10	0.73
ABC-6	69.52 ± 17.09	71.23 ± 16.27	0.74

Values are shown in median SD (minimum-maximum), *n* (%), or as otherwise indicated

ABC-6 Activities-specific Balance Confidence, *BBS* Berg Balance Scale, *KAT* kinesthetic ability trainer, *OLS* one-leg stance, *TUG* Time Up and Go

showed significantly greater improvement in the dual-task training group than in the single-task training group ($p < 0.05$) (Table 3). ABC-6 scale scores improved more in the single-task training group than in the dual-task training group ($p < 0.05$) (Table 3).

Finally, we calculated the statistical power of 0.75 for BBS, which correlated with Cohen's recommended level of 0.80 [37].

Discussion

In the present study, single- and dual-task exercises significantly improved static balance, dynamic balance, and activity-specific balance confidence in older adults with osteoporosis.

Table 2 The bone mineral density values of single- and dual-task balance training group (T-score)

Variables	Group 1 (*n*:20)	Group 2 (*n*:22)	*p*
Lumbar spine	−2.56 ± 0.67	−2.86 ± 1.15	0.31
Femur neck	−2.10 ± 0.69	−2.21 ± 1.06	0.70
Total femur	−1.94 ± 0.71	−2.03 ± 1.08	0.75

Values are mean SD or as otherwise indicated

However, the dual-task exercise program was superior to the single-task exercise program in improving BBS scores and walking speed with and without a cognitive dual-task. This study also determined that participants in the single-task balance exercise group increased their activity-specific balance confidence more than in the dual-task exercise group.

After the intervention, static balance as measured with the KAT-4000 device and OLS test improved in both groups, similar to a previous study on older adults with osteoporosis [38]. The BBS and TUG tests are most commonly used to predict dynamic and functional balance in the elderly. The minimum detectable change of the BBS has been reported to be 4 points for older adults with an initial score of 45–56 [39], with each 1 point decrease on the BBS corresponding to an increase of 6–8 % in the risk of fall among individuals who achieved between 46 and 54 [40]. In our study, after a 4-week balance training program, participants increased their BBS scores by 3.3 points in the single-task training group and 4.4 points in the dual-task training group, suggesting a 25 and a 35 % reduction in the fall risk, respectively. All participants decreased their TUG time scores below 13.5 s, a suggested cutoff point for fall risk in community-dwelling older adults [32].

Gait speed is a good indicator of functional balance, physical performance, and falls in older adults [34, 41–43]. The ability to increase gait speed is important during daily life

Table 3 The comparison of the single-task training group and dual-task training group at baseline and week 4

Variables	Group 1 (*n*:20)				Group 2 (*n*:22)				Comparison at week 4
	Baseline	Week 4	Change (95 % CI)	*p*	Baseline	Week 4	Change (95 % CI)	*p*	*p*
KAT	353.6 ± 117.95	292.7 ± 141.88	−60.90 ± 44.72	<0.001	315.0 ± 119.89	258.2 ± 114.31	−56.86 ± 16.83	<0.001	0.38
OLS	9.95 ± 4.37	14.25 ± 4.07	4.3 ± 1.21	<0.001	10.63 ± 4.22	15.36 ± 4.31	4.72 ± 0.98	<0.001	0.39
BBS	48.80 ± 1.85	52.10 ± 1.80	3.3 ± 0.47	<0.001	49.18 ± 1.86	53.39 ± 1.62	4.40 ± 0.95	<0.001	0.007*
TUG	12.70 ± 2.29	1.21 ± 0.11	−2.85 ± 0.81	<0.001	12.36 ± 2.01	9.54 ± 1.40	−2.81 ± 1.0	<0.001	0.54
Single-task gait speed	1.12 ± 0.12	1.21 ± 0.11	0.085 ± 0.023	<0.001	1.15 ± 0.10	1.28 ± 0.68	0.12 ± 0.044	<0.001	0.024
Dual-task gait speed	1.03 ± 0.11	1.05 ± 0.10	0.026 ± 0.010	<0.001	1.04 ± 0.10	1.21 ± 0.99	0.17 ± 0.020	<0.001	0.000
ABC-6	69.52 ± 17.09	79.11 ± 12.31	9.58 ± 5.88	<0.001	71.23 ± 16.27	76.27 ± 14.48	5.03 ± 3.04	<0.001	0.038

Values are mean SD for pre-post training and 95 % CI for change scores

ABC-6 Activities-specific Balance Confidence, *BBS* Berg Balance Scale, *KAT* kinesthetic ability trainer, *OLS* one-leg stance, *TUG* Time Up and Go

*Effect size Cohen d: 0.75

activities. Previous research has shown that an improvement of 0.10 m/s in single-task gait speed is considered a substantial change in older adults [34]. After our intervention program, the gait speed increased from 1.12 to 1.21 m/s in the single-task training group and from 1.15 to 1.28 m/s in the dual-task training group. Previous research has shown that 1.22 m/s is a minimum gait speed needed to cross a street at a timed crosswalk [44]. In our study, all participants in both groups significantly improved their dual-task gait speeds. However, we found that the dual-task exercise program was superior to single-task training in improving walking under single- and dual-task conditions. This finding suggests that older adults with osteoporosis are more able to develop their walking speeds under specific type of dual-task exercise programs. In recent studies, it has been shown that the ability of dual-task performance decreased due to the impact on the prefrontal cortex while performing two tasks [45]. However, studies have shown that dual-task performance ability may be improved by increasing the brain's neuroplasticity [46]. Therefore, in order to develop the targeted cognitive neuroplasticity, specific repeated type of exercises may be a good and effective approach. In addition, the practice of two tasks at the same time is crucial for improving task coordination skills and motor and cognitive performance under dual-task conditions [12].

Although participants in both exercise groups increased their activity-specific balance confidence performance after 4 weeks, the single-task balance exercise program had superior results to the dual-task program. This can be explained in two ways: firstly, a 4-week exercise program is a short period for the emergence of the positive results, and we think that this will change in the long process. Secondly, the training program, the activities we gave to the participants in the dual-task training groups were much more difficult than the tasks given to the participants in the single-task training group. As a result, participants in the dual-task training groups were confused by additional cognitive tasks, and this may have resulted in a poorly balance confidence and self-efficacy in performing daily tasks. It is also possible that changes in balance confidence do not change at the same rate as physical function. Further research is necessary.

Study limitations

The major limitations of the study were the short duration of exercise programs and follow-up. A 4-week exercise program may be insufficient to fully assess the balance. Since we analyzed only the short-term effects of balance exercise programs, further studies examining the long-term effects should be considered.

Another limitation of the study was the overwhelmingly disproportionate number of female of participants (only three

men). The study results therefore are not generalizable to older adults of both genders.

In the study, the subjects with many factors that could affect fall propensity were excluded. Although this decreases the number of variables among the participants, it may decrease the ability to generalize the results to many patients with osteoporosis.

Physical performance under dual-task conditions was quantified via using dual-task gait speed merely. Additional gait parameters (gait stability, center of mass or center of pressure and variability) can be used to evaluate balance control during simple and complex walking. At the same time, we were also able to evaluate cognitive functions while measuring motor function under dual-task conditions.

Conclusion

The results of our study confirm that 4-week dual-task and single-task balance exercise programs are effective in improving static balance, dynamic balance, and balance confidence during daily activities in older adults with osteoporosis. However, single- and dual-task gait speeds showed greater improvement following the application of a specific type of dual-task exercise programs. Therefore, we believe that additional specific types of dual-task exercise programs are needed to understand the mechanism of improving dual-task balance performance in older adults with osteoporosis.

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Compliance with ethical standards This study was carried out in accordance with the Declaration of Helsinki and was approved by the research committee of the Ufuk University School of Medicine. Written informed consent forms were provided from all participants.

Conflicts of interest None.

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