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RESEARCH PAPER

Effects of individual progressive single- and dual-task training on gait and cognition among older healthy adults: a randomized-controlled comparison study

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Key summary points

Aim With this study, we aimed to compare the effects of single- and dual-task training on gait and cognition among healthy older individuals, which can be adjusted weekly according to the individual's functional performance.

Findings According to the results of the study, the dual-task training group was better compared to the single-task training group in gait speed, cadence, and many cognitive variables.

Recommendation Individual progressive dual-task training is an effective and useful method that improves gait performance and cognitive skills among older individuals. It is proposed to implement to maintain normal gait and cognitive function, and prevent possible gait and cognitive disabilities for healthy older individuals.

Abstract

Purpose Dual-task training has beneficial effects on older individuals for gait and cognition. This study was aimed to make a comparison between the effects of individual progressive single- and dual-task training on gait and cognition among healthy older individuals.

Methods A total of 32 participants were divided randomly into two groups as the single-task group ($n=16$, 64.6 ± 3.3 years, 7 males and 9 females) and dual-task group ($n=16$, 65.6 ± 2.6 years, 8 males and 8 females). The 10-m walk test with the LEGSys device was used to assess spatio-temporal gait parameters. The cognitive parameters were evaluated using the Standardized Mini-Mental State Exam and Stroop Test. An individual progressive 60 min single- and dual-task training programs were applied twice per week for a period of 6 weeks.

Results There were significant differences for both gait and cognition variables in the dual-task training group ($p<0.05$), according to the comparison of pre- and post-treatment results. In the single-task training group, there were significant differences only in gait parameters with single-task conditions ($p<0.05$). The comparisons of the delta values between the groups indicated that the dual-task training group was better compared to the single-task training group in gait speed, cadence, and many cognitive variables ($p<0.05$).

Conclusion Individual progressive dual-task training is an effective and useful method that improves gait performance and cognitive skills among older individuals.

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Keywords Exercise training · Gait · Geriatrics · Older adults · Physiotherapy · Rehabilitation

Introduction

Gait is an important indicator of disability and mortality of older individuals [1]. Evaluating gait speed, step lengths, and gait stability provides help for insight into future falls [2, 3]. Due to aging, normal physiological changes occur in gait, including decreased gait speed, step lengths, and mediolateral hip control, increased step width, and prolonged stance phase. The decrease in gait speed is the most consistent change due to aging. Gait speed less than 1.0 m/s is considered abnormal and it decreases by about 1% per year from the age of 60 years [4].

Gait is a complex process that integrates sensory input from visual, vestibular, and proprioceptive systems, and combines with appropriate muscle strength, neuromuscular timing, and joint mobility [5, 6]. This complex process among older individuals is associated with cognitive skills and significant changes in gait are indicative for falls, dementia, and disability. In addition, there is an association between slower gait speed and unstable gait in single- and dual-task conditions, and the early period of constraints in cognitive domains like executive function, attention, and working memory. Decreasing cognitive ability in the late period manifests itself with inactivity and falling [7].

Recently, dual-task training, described as the simultaneous practice of cognitive and motor tasks, has been included in the geriatric rehabilitation approach for the improvement of gait and cognitive performance in older adults. Recent studies have shown the beneficial effects of dual-task training on gait in single- and dual-task conditions among older individuals [8–10]. The systematic review study of Wollesen et al. [11] has emphasized that the training program should include a certain level of exercise loads such as increased difficulties, appropriate intensity and duration, level of task specificity, and variable task prioritization, to achieve more beneficial effects of dual-task training. In a systematic review by Sherrington et al. [12], which evaluated exercises that prevent falls in older individuals, it was stated that there are insufficient studies to prove the superiority of group or individual exercises. In the literature, group training has been applied in studies comparing the effect of single- and dual-task training on the gait performance of older adults. Therefore, unlike other studies, individual single- and dual-task training were applied in this study to be able to adjust the exercise load according to the individual's functional performance. This study was aimed to make a comparison between the effects of individual progressive single- and dual-task training on gait and cognition among healthy older adults.

Method

Participants

The study included community-dwelling older individuals with an age range of 60–75 years and who met the criteria to be included for this study. For the participants of the study, the older individuals who came to the Refreshment University established for older individuals at Akdeniz University were contacted between November 2018 and March 2020. With the randomization method, participants have been divided into a group of two: dual-task training group (DTT) ($n = 16$, 8 males—8 females) and single-task training group (STT) ($n = 16$, 7 males—9 females). Randomization was stratified with the Timed Up and Go Test scores range (< 10 s and ≥ 10 s) according to cut-off value for mobility impairment. Then, the training groups were formed by taking an equal number of samples from each stratum group randomly using Microsoft Excel.

The inclusion criteria were: to be the age of 60–75 years, with the educational level of at least primary school, the Standardized Mini-Mental State Exam score of 24 or greater, and the ability to walk independently without an assisting device. The exclusion criteria of the study were the presence of any acute or chronic disease that may affect the training (e.g., Parkinson's disease, diabetes mellitus, psychiatric diseases), any significant hearing or visual impairments, drug use that would affect the study results or participation in regular exercise programs within the last 6 months.

Outcome measures

All evaluations were applied, before and after the 6-week training with the same environmental conditions, by a physiotherapist with a clinical experience of 10 years. Standard test protocols were followed during the evaluations.

The face-to-face interview method was used to record the participants' demographic data on the registration form. The 10-m walk test was applied to evaluate gait parameters. The main outcome is gait speed for this study, because the sample size of the study was created by considering this variable. The Timed Up and Go (TUG) test is used to randomized the participants based on their functional mobility. Scores from the Standardized Mini-Mental State Exam and Stroop Test were among the recorded cognitive data.

The 10-m walk test was applied with the LEGSys device (Newton, MA/USA). The portable sensors of the device were placed above the participant's ankles for the test. Before and after the 10-m marked test area, a 2 m distance area was included for starting and ending gait, where the gait parameters were not evaluated. The participant was asked to walk at natural gait speed. Measurements were initiated as soon as the individual's foot stepped over the start line and ended when it crossed the finish line [13].

The TUG test is used broadly in the rehabilitation of older individuals to investigate balance, gait speed, and functional ability needed for the performance of basic activities of daily living in older persons. The TUG test records the time, in seconds, from the moment a participant gets up from the chair until it takes a 3-m walk at a natural speed, turns back and sits back on the chair. A stopwatch was used to record the time during the test [14, 15].

As a valid and reliable instrument, The Standardized Mini-Mental State Exam is applied commonly to scan cognitive disabilities in older individuals. It supplies a global score of cognitive ability which has a correlation with function in activities of daily life. The test which consists of 19 items and memory, attention, visual-spatial skills, orientation, and language functions subgroups was applied per the instruction of Kalem et al. [16]. The cut-off point for mild and moderate dementia in Turkey has been calculated as 23/24 [16].

The Stroop Test assesses selective attention and inhibition. The test consists of a word, a color, and a color word interference page and five distinct tests as follows: 1. saying the color names from a card where they are written in black, 2. saying the color names from a card where they are written in different colors, 3.saying the colors of circles shown on a card with colored circles, 4. saying the colors of words on a card with neutral words written in color, and 5. saying the names of colors shown on a card with the color names written using different colors. It was applied in line with the "Turkish form application and scoring" standard instruction prepared by Karakaş et al. A stopwatch was used to record the time during the test [17].

Interventions

STT and DTT groups were put into an individual progressive 60 min single- and dual-task training programs twice per week for a period of 6 weeks. All training programs were implemented individually by the same physiotherapist. The physiotherapist giving the training has 10 years of clinical experience. The initial and final 10 min of the main training had warm-up and cooling exercises including breathing and stretching exercises for the upper and lower body. The STT program consists of basic gait and balance exercises (motor tasks). The DTT program included the same motor tasks which were concurrent with a variety of cognitive tasks, designed to induce the focus of attention (Table 1) [10]. All these trainings included different levels which were progressively complex, adjustable to individual abilities and tolerability [18]. The intensity of both training programs was progressively increased or decreased weekly, based on the ability of each participant. When the participants managed to adapt to a certain training level, new challenges (e.g., longer time) were added to them [19]. There were not any unexpected effects during the exercise. The exercises were performed in the exercise room of the Department of Gerontology at Akdeniz University. The rooms were suitable for physical training activities with proper lighting and natural ventilation. All the participants in both groups attended the intervention program.

Design

This study was designed as a randomized-controlled study with parallel groups to evaluate the effects of individual progressive DTT on gait and cognition among healthy older individuals compared with an STT. The study was conducted in accordance with the ethical standards mentioned in the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards. All the participants gave their informed consent for inclusion written after they were verbally briefed about the aims of the study. The Non-Interventional Clinical Research Ethics Committee of Pamukkale University approved the protocol of the study (Ref. No: 60116787-020/53283).

Sample size

The effect size obtained from the reference study was very strong according to gait speed results ($d = 3.94$) (12). Assuming a lower level of power would be obtained, the calculation was done according to the outcome of the power analysis that at least 16 participants in each 2 groups (total 32 participants) can achieve 80% power at a 95% confidence level for $d = 0.9$ effect size [20].

Statistical analysis

SPSS version 22.0 (IBM statistics Armonk, NY, USA) was used for the data analysis. Descriptive statistics were presented as mean ± standard deviation (SD) values, number (n), and percentage (%). The normal distribution of the parameters was determined with the Shapiro–Wilk test. The Mann–Whitney U test (non-parametric) was used to compare the score differences between both groups for each variable. The Wilcoxon Signed-Rank (non-parametric) test was used for the analysis of pre—and post-training observations. Statistical significance was accepted as $p < 0.05$.

Table 1 Motor and cognitive tasks practised in the trainings

Motor Tasks	Progression	Cognitive tasks	Progression
Standing	*First week: semi-tandem Additional challenges: Longer time (to 1 min) Reduced visual input (e.g. looking up to the sky or closing their eyes) Less support surface (to tandem) *Tandem Same challenges were added	Recalling a sequence of numbers previously given	First week: Sequence included 4 numbers Additional challenge: increased sequence of numbers gradually
Single leg standing	First week: single leg standing Additional challenges: Longer time (to 1 min) Reduced visual input (e.g. looking up to the sky or closing their eyes)	Drawing a letter or a word on the floor by a foot	First week: drawing one letter Additional challenge: drawing a word (formed by two letters, three letters… etc.)
Walking exercises: 1-Forward 2- Side by side 3- Backward	*First week: walking as usual Additional challenges: Increased speed Longer time Reduced visual input (e.g. looking up to the sky or closing their eyes) Less support surface (semi-tandem) *Semi-tandem walking Same challenges were added *Tandem walking Same challenges were added	1-Saying the previous number from a number between 0 and 100 given by trainer 2-Collecting numbers 3-Counting forward by ones numbers between 0–100	1-First week: Saying the previous number Additional challenge: subtracting 2, 3… etc. from the given number 2-First week: Collecting single digit numbers Additional challenge: increased scalar-valued of the numbers 3-First week: Counting forward by ones Additional challenge: counting forward by twos, threes and fours etc. gradually
Reaching exercises: 1-Forward 2-Both sides	First week: Reaching as far as possible Additional challenges: Longer time Reduced visual input (e.g. looking up to the sky or closing their eyes) Increased distance	1-Counting backward by ones numbers between 0–100 2-Saying the next number from a number between 0–100 given by trainer	1-First week: Counting backward by ones Additional challenge: counting backward by twos, threes and fours etc. Gradually 2-First week: Saying the next number Additional challenge: subtracting 2, 3… etc. from the given number

Results

The Consolidated Standards of Reporting Trials (CONSORT) diagram of the participants is presented in Fig. 1. The study was completed with 32 participants. After the first evaluation and randomization of 37 individuals, two individuals did not attend the training program in both the STT and DTT group, and one individual wished to leave the training program in DTT group. The DTT group comprised eight females and eight males, with a mean age of 64.6 ± 3.3 years, and the STT group comprised nine females and seven males with a mean age of 65.6 ± 2.6 years. When the age, height, weight, BMI, education level, or TUG test scores were compared for the groups, there was no statistically significant difference. The demographic data of all the participants are presented in Table 2.

When the comparison of pre- and post-treatment evaluation of the DTT group was done, there was a significant difference in gait speed, cadence and step lengths, and cognitive status in both single- and dual-task conditions ($p < 0.05$). In single-task conditions, there were significant differences in gait speed, cadence, and step lengths in the STT group ($p < 0.05$), and no differences were found in dual-task conditions ($p > 0.05$). There was no significant difference in cognitive status in the STT group ($p > 0.05$).

Delta (Δ) values were calculated to investigate the differences between the groups after treatment. When these were compared between the groups, the dual-task group was better than the single-task group in gait speed, cadence, the Standardized Mini-Mental State Exam scores, and 1st, 2nd, and 3rd tests of the Stroop Test ($p < 0.05$, Table 3).

Discussion

Many recent studies have been carried out on the fact that dual-task training has beneficial effects on gait as well as preventing falls in older individuals. However, each study has implemented different protocols in terms of training programs. This study was aimed at comparing the effects of single- and dual-task training on gait and cognition among healthy older individuals, which can be adjusted weekly

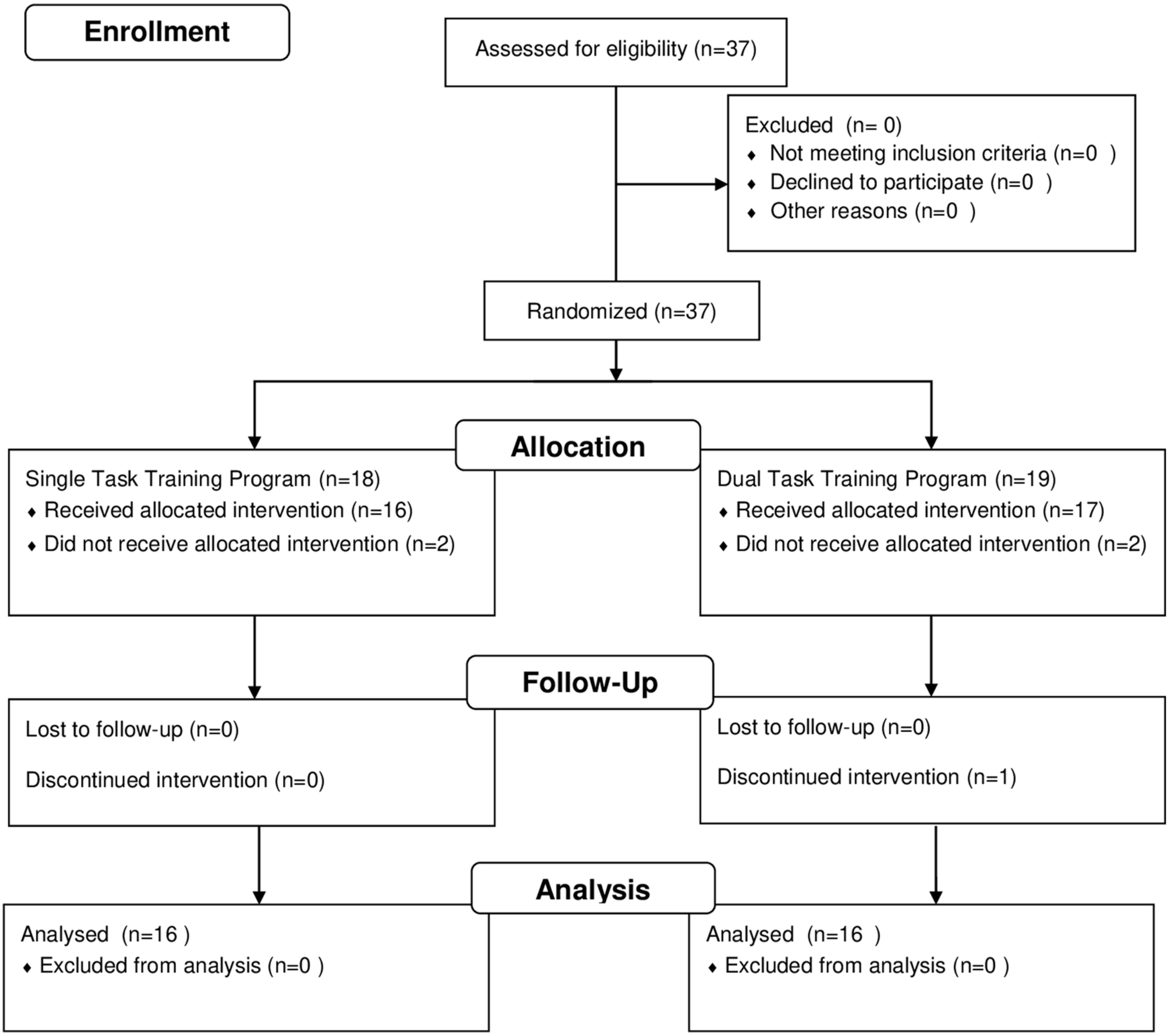

Fig. 1 Participant flowchart

Table 2 Comparison of groups in terms of demographic data

Variables	ST group ($n = 16$) $X \pm$ SD	DT group ($n = 16$) $X \pm$ SD	p value
Age (year)	64.6 ± 3.3	65.6 ± 2.6	0.518
BMI (kg/cm^2)	24.74 ± 3.68	25.05 ± 3.44	0.637
Education (year)	12.7 ± 3.6	14.0 ± 2.5	0.371
TUG (s)	10.4 ± 1.7	10.0 ± 1.5	0.290

ST single task, *DT* dual task, *BMI* body mass index, *TUG* timed up and go test

according to the individual's functional performance and given one by one.

The results of the study show that after applying dual-task training, the cognitive status of healthy older individuals improved and gait performance increased in both single- and dual-task conditions. After the STT, only gait speed, cadence, and step lengths showed improvements in the single-task conditions. The DTT group participants were better than the STT group in terms of all parameters except step lengths when the comparison of differences was carried out between the groups. In the STT group, the results were as expected which were that the gait performance under the dual-task conditions and cognitive status would not improve. In terms of gait parameters, DTT is more beneficial in both single- and dual-task conditions. The result of the study indicates that DTT which is based

Table 3 Intra- and inter-group comparisons of balance and functional mobility before and after training

Variables	STT group (n = 16) $X \pm$ SD			DTT group (n = 16) $X \pm$ SD			p value
	Pre-training	Post-training	Mean change (95% CI)	Pre-training	Post-training	Mean Change (95% CI)	
Gait speed$_{single}$	1.11 ± 0.18	1.22 ± 0.19	**0.11 ± 0.06**†	1.21 ± 0.10	1.38 ± 0.08	**0.17 ± 0.06**†	**0.022***
Cadence$_{single}$	108.5 ± 13.6	111.6 ± 10.5	**3.1 ± 5.0**†	102.6 ± 9.5	110.5 ± 8.9	**7.9 ± 3.0**†	**0.004***
Left step length$_{single}$	0.66 ± 0.09	0.73 ± 0.09	**0.06 ± 1.1**†	0.70 ± 0.05	0.78 ± 0.11	**0.07 ± 0.10**†	0.784
Right step length$_{single}$	0.64 ± 0.08	0.69 ± 0.08	**0.05 ± 0.09**†	0.68 ± 0.08	0.74 ± 0.08	**0.06 ± 0.09**†	0.272
Gait speed$_{dual}$	1.03 ± 0.21	1.07 ± 0.24	0.04 ± 0.14	1.08 ± 1.20	1.32 ± 1.11	**0.24 ± 0.16**†	**0.001***
Cadence$_{dual}$	98.9 ± 14.7	98.6 ± 15.4	− 0.32 ± 6.9	91.0 ± 13.3	101.8 ± 9.4	**10.8 ± 6.8**†	**0.000***
Left step length$_{dual}$	0.67 ± 0.09	0.71 ± 0.09	0.04 ± 0.14	0.67 ± 0.04	0.81 ± 0.13	**0.14 ± 0.14**†	0.125
Right step length$_{dual}$	0.65 ± 0.72	0.65 ± 0.06	0.00 ± 0.08	0.68 ± 0.06	0.77 ± 1.1	**0.09 ± 0.12**†	**0.006***
Stroop test (s)							
1. Test	11.7 ± 2.4	11.5 ± 1.9	− 0.22 ± 1.7	11.5 ± 2.3	9.9 ± 2.2	**− 1.6 ± 1.5**†	**0.002***
2. Test	12.5 ± 2.8	14.0 ± 3.9	1.5 ± 3.0	12.7 ± 2.5	11.3 ± 2.1	**− 1.3 ± 1.0**†	**0.000***
3. Test	11.5 ± 1.9	11.4 ± 1.7	− 0.11 ± 1.4	12.7 ± 2.5	10.9 ± 1.9	**− 1.8 ± 1.1**†	**0.001***
4. Test	22.6 ± 4.0	21.1 ± 3.8	− 1.5 ± 3.0	20.3 ± 4.1	18.7 ± 4.5	**− 1.6 ± 1.4**†	0.059
5. Test	29.3 ± 5.6	28.3 ± 6.7	− 1.0 ± 3.6	28.0 ± 6.8	24.7 ± 4.5	**− 3.3 ± 3.9**†	0.070
SMMSE total score	26.7 ± 1.6	26.8 ± 1.6	0.08 ± 0.87	26.4 ± 0.96	28.7 ± 1.6	**2.5 ± 1.6**†	**0.000***

TUG timed up and go test, *SMMSE* standardized mini-mental state exam

p value refers to inter-group comparisons

†Significant change in intra-group comparisons, Wilcoxon test

*Significant change in inter-group comparisons, Mann–Whitney *U* test

Bold values indicate p < 0.05

on simultaneously stimulating both cognitive processes and motor skills such as gait may contribute more to the development of motor performance. In other words, the difference between the two models of training may be due to the transfer of additional cognitive gains acquired through DTT to motor performance. Many studies in the literature support this outcome. There are studies showing the association between cognitive performance and gait in older individuals [21, 22]. While gait is defined as an automatic motor task mainly, cognitive ability organizes control over axial musculature and balance/posture with bilateral upper and lower extremity movements and integration of visual, vestibular, proprioceptive, and other sensory feedback. Executive function and process speed are cognitive areas associated with the spatio-temporal gait parameters; especially, impaired executive function causes a decrease in gait speed over time, thus leading to gait dysfunction [23]. However, Falbo et al. [8] suggest that effective executive function is not enough by itself to improve the health and quality of life in older individuals; hence, dual tasks similar to daily life activities, such as gait performance under dual-task conditions, should be developed together with executive function gait performance under dual-task conditions, and by serving this purpose, dual-task training would be an appropriate method of maintaining health. Also, Rigoli et al. [24] described other cognitive domains such as working memory and inhibitory control that have a positive association with motor coordination. In addition, some studies suggest that the executive function responsible for the coordination of multitasking could be quite improved in older individuals and the abilities captured in training could transfer to a novel dual-task [25–27]. According to Kramer et al. [25], DTT should be consistently adjustable and individual through feedbacks from participants' performance during training sessions and should include task priorities.

In the literature, group training has been used in studies comparing STT and DTT in healthy older individuals [9, 10, 28]. Similar to this study, only one earlier study practiced both individual training and cognitive tasks in the DTTs personalized to the performance of participants on the basis of the clinical assessment of the therapist. In that study, evaluation of the results of DTT before and after the training showed that gait speed and stride lengths increased in both single- and dual-task conditions, and also there was an improvement in the cognitive performance of participants. Single-task training was not used for the participants in that study [29].

When considering the results of other comparative studies including group training in the literature, in the study by Fraser et al. [28], gait performance improved in both STT and DTT groups. In terms of gait performance, neither of the training groups showed any superiority over the other. The groups with cognitive training had higher score changes compared to those without [28]. Wollesen et al. [9] compared STT and DTT in terms of gait performance in older individuals and reported that gait performance improved, while cognitive performance did not change. Also, the DTT group had the most improvement in gait according to the data of the study. In another DTT comparison study in older individuals in regards to falling concern, Wollesen et al. [10] demonstrated similar results. A progressive group DTT including task-managing strategies (task switching and task prioritization) was compared to a non-training control group. Both intervention groups with and without concern of falling showed a significantly improved gait performance in single- and dual-task conditions. Also, cognitive performance during walking showed no improvement in people with the concern of falling. In the literature, there are differences between the results of the comparative studies on DTT, for which the main reasons can be related due to the fact that different gait assessments were performed and different training protocols were applied. Unlike other studies, the DTT applied in this study significantly improved both gait parameters and cognitive ability. The reason for this difference could be attributed to the delivery of individual training and the implementation of a training model adapted to the individual's functional performance. There may be a need for more individual training for the improvement of the cognitive domains and gait performance. Supporting these outcomes, Brum et al. [30], compared the efficiency of the group and individual training working memory training on working memory and other cognitive abilities. According to the results of the study, individual training might be more beneficial as the group training format may not be suitable for participants with lower education because of the dual-task nature of the training activity. However, Sherrington et al. [12], who assessed the positive and negative effects of exercise interventions for preventing falls in older individuals living in the community in a systematic review study, did not detect any differences in the outcomes of individual and group exercise interventions according to the analysis of the study. There were no studies comparing the effects of individual and group DTT in the literature.

One of the limitations of this study was that task switching and task prioritization were not used in training, because they caused confusion for older individuals during training. Other limitations were the -ample size of the training groups and no blinding applied for the participants or the physiotherapist who supervised the training. Therefore, the risk of bias for evaluations and training may have occurred. The strength of the study is that it was a randomized-controlled study, an individual progressive training program was delivered to the participants and providing guidance for forming a DTT protocol with the purpose of improvement in gait and cognition in older individuals.

As a result, individual progressive DTT is an effective and useful method that improves gait performance and cognitive skills among healthy older adults. It is proposed to implement to maintain normal gait and cognitive function and prevent possible gait and cognitive disabilities for healthy older individuals. Nevertheless, there is a need for further studies comparing individual and group DTTs.

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Data availability The authors confirm that the data supporting the findings of this study are available within the article [and/or] its supplementary materials.

Compliance with ethical standards

Conflict of interest/Competing Interests The authors declare that they have no conflict of interest/competing interest to declare that are relevant to the content of this article. The authors did not receive support from any organization for the submitted work.

Ethical approval This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Ethics Committee of University B (Date: 08/08/2018 No. 60116787-020/53283).

Informed consent Written informed consent was obtained from all participants after they were verbally briefed about the aims of the study.

References

1. Abe T, Kitamura A, Taniguchi Y, Amano H, Seino S, Yokoyama Y et al (2019) Pathway from gait speed to incidence of disability and mortality in older adults: a mediating role of physical activity. Maturitas 123:32–36. https://doi.org/10.1016/j.maturitas.2019.02.002
2. Freire Junior RC, Porto JM, Rodrigues NC, Brunelli RM, Braga LF, de Abreu DC (2016) Spatial and temporal gait characteristics in pre-frail community-dwelling older adults. Geriatr Gerontol Int 16(10):1102–1108. https://doi.org/10.1111/ggi.12594
3. Marques NR, Spinoso DH, Cardoso BC, Moreno VC, Kuroda MH, Navega MT (2018) Is it possible to predict falls in older adults using gait kinematics? Clin Biomech (Bristol, Avon) 59:15–18. https://doi.org/10.1016/j.clinbiomech.2018.08.006
4. Cruz-Jimenez M (2017) Normal changes in gait and mobility problems in the elderly. Phys Med Rehabil Clin N Am 28(4):713–725. https://doi.org/10.1016/j.pmr.2017.06.005
5. Prince F, Corriveau H, Hébert R, Winter DA (1997) Gait in the elderly. Gait Posture 5(2):128–135. https://doi.org/10.1016/S0966-6362(97)01118-1
6. Smith E, Cusack T, Cunningham C, Blake C (2017) The influence of a cognitive dual task on the gait parameters of healthy older

adults: a systematic review and meta-analysis. J Aging Phys Act 25(4):671–686. https://doi.org/10.1123/japa.2016-0265

7. Montero-Odasso M, Verghese J, Beauchet O, Hausdorff JM (2012) Gait and cognition: a complementary approach to understanding brain function and the risk of falling. J Am Geriatr Soc 60(11):2127–2136. https://doi.org/10.1111/j.1532-5415.2012.04209.x
8. Falbo S, Condello G, Capranica L, Forte R, Pesce C (2016) Effects of physical-cognitive dual task training on executive function and gait performance in older adults: a randomized controlled trial. Biomed Res Int 2016:5812092. https://doi.org/10.1155/2016/5812092
9. Wollesen B, Mattes K, Schulz S, Bischoff LL, Seydell L, Bell JW et al (2017) Effects of dual-task management and resistance training on gait performance in older individuals: a randomized controlled trial. Front Aging Neurosci 9:415. https://doi.org/10.3389/fnagi.2017.00415
10. Wollesen B, Schulz S, Seydell L, Delbaere K (2017) Does dual task training improve walking performance of older adults with concern of falling? BMC Geriatr 17(1):213. https://doi.org/10.1186/s12877-017-0610-5
11. Wollesen B, Voelcker-Rehage C (2013) Training effects on motor–cognitive dual-task performance in older adults. Eur Rev Aging Phys Act 11(1):5–24. https://doi.org/10.1007/s11556-013-0122-z
12. Sherrington C, Fairhall NJ, Wallbank GK, Tiedemann A, Michaleff ZA, Howard K et al (2019) Exercise for preventing falls in older people living in the community. Cochrane Database Syst Rev. 1:CD012424. https://doi.org/10.1002/14651858.CD012424.pub2
13. Peters DM, Fritz SL, Krotish DE (2013) Assessing the reliability and validity of a shorter walk test compared with the 10-meter walk test for measurements of gait speed in healthy, older adults. J Geriatr Phys Ther 36(1):24–30. https://doi.org/10.1519/JPT.0b013e318248e20d
14. Podsiadlo D, Richardson S (1991) The timed "Up & Go": a test of basic functional mobility for frail elderly persons. J Am Geriatr Soc 39(2):142–148. https://doi.org/10.1111/j.1532-5415.1991.tb01616.x
15. Beauchet O, Fantino B, Allali G, Muir SW, Montero-Odasso M, Annweiler C (2011) Timed Up and Go test and risk of falls in older adults: a systematic review. J Nutr Health Aging 15(10):933–938. https://doi.org/10.1007/s12603-011-0062-0
16. Kalem ŞA, Öktem Ö, Emre M (2002) Kısa Blessed Oryantasyon-Bellek-Konsantrasyon Testi (BOMC) ve Standardize Mini Mental Test (SMMT) betimsel istatistik değerlerinin bir normal erişkin Türk örnekleminde saptanması. Nöropsikiyatr Arş 39(2–3–4):95–102
17. Karakaş S, Erdoğan E, Sak L, Alkan S (1999) Stroop Testi TBAG Formu: Türk kültürüne standardizasyon çalışmaları, güvenirlik ve geçerlik. Klin Psikiyatr Derg 2:75–88
18. Brustio PR, Rabaglietti E, Formica S, Liubicich ME (2018) Dual-task training in older adults: The effect of additional motor tasks on mobility performance. Arch Gerontol Geriatr 75:119–124. https://doi.org/10.1016/j.archger.2017.12.003
19. van het Reve E, de Bruin ED (2014) Strength-balance supplemented with computerized cognitive training to improve dual task gait and divided attention in older adults: a multicenter randomized-controlled trial. BMC Geriatr 14:134. https://doi.org/10.1186/1471-2318-14-134
20. Shin SS, An DH (2014) The effect of motor dual-task balance training on balance and gait of elderly women. J Phys Ther Sci 26(3):359–361. https://doi.org/10.1589/jpts.26.359
21. Kikkert LHJ, Vuillerme N, van Campen JP, Appels BA, Hortobágyi T, Lamoth CJC (2018) The relationship between gait dynamics and future cognitive decline: a prospective pilot study in geriatric patients. Int Psychogeriatr 30(9):1301–1309. https://doi.org/10.1017/s1041610217002770
22. Toots ATM, Taylor ME, Lord SR, Close JCT (2019) Associations between gait speed and cognitive domains in older people with cognitive impairment. J Alzheimers Dis 71(s1):S15-s21. https://doi.org/10.3233/jad-181173
23. Cohen JA, Verghese J, Zwerling JL (2016) Cognition and gait in older people. Maturitas 93:73–77. https://doi.org/10.1016/j.maturitas.2016.05.005
24. Rigoli D, Piek JP, Kane R, Oosterlaan J (2012) An examination of the relationship between motor coordination and executive functions in adolescents. Dev Med Child Neurol 54(11):1025–1031. https://doi.org/10.1111/j.1469-8749.2012.04403.x
25. Kramer AF, Larish JL (1996) Aging and dual-task performance. In: Rogers WA, Fisk AD, Walker N (eds) Aging and skilled performance: advances in theory and applications. Lawrence Erlbaum Associates, Inc, Hillsdale, pp 83–112
26. McDowd JM, Shaw RJ (2000) Attention and aging: A functional perspective. In: Craik FIM, Salthouse TA (eds) The handbook of aging and cognition, 2nd edn. Lawrence Erlbaum Associates Publishers, Mahwah, pp 221–292
27. Kramer AF, Larish JL, Weber TA, Bardell L (1999) Training for executive control: Task coordination strategies and aging. In: Gopher D, Koriat A (eds) Attention and performance. Attention and performance XVII: cognitive regulation of performance: interaction of theory and application. MIT, Cambridge, pp 617–652
28. Fraser SA, Li KZ, Berryman N, Desjardins-Crepeau L, Lussier M, Vadaga K et al (2016) Does combined physical and cognitive training improve dual-task balance and gait outcomes in sedentary older adults? Front Hum Neurosci 10:688. https://doi.org/10.3389/fnhum.2016.00688
29. Dorfman M, Herman T, Brozgol M, Shema S, Weiss A, Hausdorff JM et al (2014) Dual-task training on a treadmill to improve gait and cognitive function in elderly idiopathic fallers. J Neurol Phys Ther 38(4):246–253. https://doi.org/10.1097/NPT.0000000000000057
30. Brum PS, Borella E, Carretti B, Yassuda MS (2020) Working memory training format in older adults: individual versus group sessions. Aging Clin Exp Res. https://doi.org/10.1007/s40520-019-01468-0