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ORIGINAL ARTICLE

Effects of single-task, dual-task and successive physical-cognitive training on fall risk and balance performance in older adults: a randomized trial

Leyla ATAŞ BALCI[1], Kübra SOĞUKKANLI KADAK[2], Sinem Burcu ERDOĞAN[3], Lütfü HANOĞLU[4]

Purpose: This study aimed to examine the effects of single-task, dual-task and successive physical-cognitive training on fall risk, balance, and gait performances in elderly.

Methods: A total of 45 healthy older adults (73.0±4.6 years; 6 male and 39 female) underwent one of three interventions 3 times a week for 4 weeks. Group-1 performed single-task balance and gait exercises. Group-2 performed cognitive activity, balance, and gait exercises simultaneously. Group-3 performed successive cognitive activities and balance and gait exercises. Gait speed under single-task and dual-task conditions, Berg Balance Scale, Timed up and Go test, and Tinetti's Falls Efficacy Scale scores were evaluated before and after 4 weeks of interventions.

Results: Gait speed under single-task condition, Timed up and Go Test, and Berg Balance Scale scores were improved in all groups ($p<0.05$). Gait speed under dual-task condition was improved in Groups-2 and 3 ($p<0.05$). Group-3 had greater improvement in Berg Balance Scale and Timed up and Go test scores than Group-2. Tinetti's Falls Efficacy Scale was improved in Group-1 and 3 after training while the improvement was greater in Group-3 ($p=0.001$).

Conclusion: The present study suggests that an intervention involving cognitive and physical activities results in greater improvement in gait speed than interventions involving physical activities alone. However, successive physical-cognitive training may be more effective in reducing fear of fall and improving balance skills in elderly.

Keywords: Falls, Exercise, Postural balance, Aged, Gait.

Yaşlı bireylerde tek-görev, çift-görev ve ardışık fiziksel-bilişsel eğitimin düşme riski ve denge performansı üzerine etkileri: randomize çalışma

Amaç: Bu çalışma, tek görev, çift görev ve ardışık fiziksel-bilişsel eğitimin yaşlı erişkinlerde düşme riski, denge ve yürüme performansları üzerindeki etkilerini incelemek amacıyla yapıldı.

Yöntem: Toplam 45 sağlıklı yaşlı yetişkine (73,0±4,6 yıl; 6 erkek ve 39 kadın) haftanın 3 günü 4 hafta üç müdahaleden biri uygulandı. Grup-1'e tekli görev denge ve yürüyüş egzersizleri yaptırıldı. Grup-2 eş zamanlı olarak bilişsel aktivite, denge ve yürüyüş egzersizleri yaptı. Grup-3 birbirini takip eden bilişsel aktiviteler, denge ve yürüyüş egzersizleri gerçekleştirdi. Dört haftalık müdahalelerden önce ve sonra tek ve çift görev koşullarında yürüyüş hızı, Süreli Kalk Yürü Testi, Berg Denge Ölçeği ve Tinetti'nin Düşme Etkinlik Ölçeği puanları değerlendirildi.

Bulgular: Tüm gruplarda tek görev koşulu altında yürüyüş hızı, Berg Denge Ölçeği ve Süreli Kalk Yürü Testi puanları düzeldi ($p<0,05$). Grup 2 ve 3'te çift görev koşulu altında yürüyüş hızı düzeldi ($p<0,05$). Grup-3'ün, Süreli Kalk Yürü Testi ve Berg Denge Ölçeği puanlarında Grup-2'den daha fazla düzelme görüldü. Tinetti'nin Düşme Etkinlik Ölçeği puanları, Grup-1 ve 3'te düzelirken, Grup-3'te düzelme daha yüksekti ($p=0,001$).

Sonuç: Bu çalışma yürüyüş hızında, bilişsel ve fiziksel aktiviteleri içeren bir müdahalenin, sadece fiziksel aktiviteleri içeren müdahalelere göre daha fazla düzelmeye yol açtığını göstermektedir. Birbirini takip eden fiziksel-bilişsel eğitim, denge becerilerini geliştirme ve yaşlılarda düşme korkusunu azaltmada daha etkili olabileceği düşünüldü.

Anahtar kelimeler: Düşmeler, Egzersiz, Postüral denge, Yaşlı, Yürüyüş.

1: Bahcesehir University, Department of Physiotherapy and Rehabilitation, Istanbul, Turkey
2: Istanbul Medipol University, Department of Neuroscience, Istanbul, Turkey.
3: Acıbadem University, Department of Medical Engineering, Istanbul, Turkey.
4: Istanbul Medipol University, Department of Neurology, Istanbul, Turkey.
Corresponding Author: Leyla Atas Balcı: leyla.atasbalci@hes.bau.edu.tr
ORCID IDs (order of authors): 0000-0002-3302-3722; 0000-0002-9855-8859; 0000-0001-6028-3477; 0000-0003-4292-5717
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Falls, the second leading cause of accidental injury, is a main risk factor of mortality for elderly.[1,2] Falls may be caused by environmental factors (such as slippery flooring and uneven streets), vision deficits, balance and gait impairments, chronic diseases, history of falls, confusion, postural hypotension, syncope, drugs and dementia.[3,4] Gait and balance disturbances are the main intrinsic factors of falls. The causes of gait disturbances involve loss of muscle strength, visual impairment, cognitive impairment, loss of sensory inputs and slower reaction time.[3,5] The risk of falling among the elderly is increased by decreased gait speed.[6] Especially, decreases in gait speed while walking with performing cognitive task increases fall risks in older individuals.[7]

The fall preventive intervention strategies include determination of risk factors, medical interventions, environmental modifications, psychological approaches, assistive devices and exercise programs including walking, strengthening and balance exercises.[1,2,5,7] Recent studies have demonstrated the effectiveness of physical activity-based approaches for fall prevention where exercises based on cognitive-motor intervention training such as performing cognitive activities simultaneously with gait and balance exercises have been promising.[8]

Executive functions related to reasoning, planning, sequencing, adapting to environmental stimuli, changing behaviors appropriately, and solving complex problems, may effect one's ability to walk safely and efficiently.[9] These functions are crucial for developing inner strategies (e.g., decision-making capacities during walking in a complex environment adaptation to ground changes, response inhibition allowing one to concentrate on walking or cognitive task) to avoid fall accidents among the elderly.[10] Executive functions may decline with aging due to decreased number of neurons and shrinkage of the cortical regions.[11] This may lead to an increase in metabolic cost of dual-task and consequently an increase in fall risk.[12]

The term "dual-task" means that the ability of performing two tasks at the same time. Many activities in daily life require simultaneous performance of cognitive and motor tasks such as walking during talking. According to the capacity-sharing theory,[13] two attention-demanding tasks will cause deterioration of at least one of the tasks. Therefore, cognitive task performance while walking may result in decreased gait speed and/or delayed cognitive task performance.[14] Daily living activities requiring dual-task performance can cause fall risk in older adults if they have trouble separating their attention between cognitive and motor tasks.[10]

Previous researches pointed out that dual-task training is more efficacious than single-task training in reducing falls among the elderly.[15,16] Especially, dual task training consisting of cognitive and motor activities has been shown to be more effective than single-task training in reducing falls among the elderly with greater improvements in gait initiation and managing divided attention.[17] There is also evidence that consecutive exercise-cognitive training may improve cognitive function in elderly more than either cognitive or exercise training alone.[18] Another study by Ruthruff et al.[19] showed compelling evidence that practicing single-task provides to automate the performance of each task. However, to date, there have been no studies that compared the effects of single-task training, dual-task training, and successive physical-cognitive training on fall risk among the healthy older individuals.

The purpose of this study was to compare the effects of single-task training, dual-task training and successive physical-cognitive training on fall risk, gait, and balance performances in elderly at risk of fall. We hypothesized that performing cognitive activity and physical exercises successively may reduce fall risk more than single-task and dual-task training with greater improvements in executive functions, balance, and gait performance. The rationale behind this hypothesis relies on previous evidence from animal studies which showed that physical exercise promotes formation of neurons in the brain,[20] while cognitive training regulates synaptic formation between these new neurons.[21] Therefore, we hypothesize that exposure to exercise and cognitive activities sequentially may improve the survival of exercise-induced neurons and be more effective in reducing fall risk.

METHODS

Forty-five healthy elderly people who applied to the Division of Neurology, Istanbul Medipol University Hospital, between January 2015 and November 2016 participated in this study. The Ethics Committee of Istanbul Medipol University reviewed and approved the present study (14.12.2015/10840098-604.01.01-E.4629). All experiments were carried out in accordance with the Declaration of Helsinki. Written informed consent was obtained from all participants. The present study was registered retrospectively (clinicaltrials.gov: NCT03189342).

The participant inclusion criteria were as follows: age 65 years or older, literate, having a fall incident during the past year, ability to walk 10 meters without any support, getting more than 13.5 seconds at Timed up and Go test (TUG)[22] and scoring more than 24 points at Standardized Mini-Mental State Examination (SMMSE).[23] The exclusion criteria were as follows: Neurological or musculoskeletal diagnosis such as Parkinson's or Alzheimer's disease, orthopedic involvement or significant visual and auditory impairments.

SMMSE was applied to assess general state of cognitive function.[23] This assessment tool consists of registration, orientation, attention, calculation, language, recall and visual constructive praxis categories that evaluate specific cognitive functions. The score higher than or equal to 24 points reveals a normal cognition.

The following outcome measurements were completed before and after the intervention periods on all participants.

Gait speed was measured under single-task and dual-task conditions. In the single-task condition, participants walked 10 meters at their normal pace and the time to complete the task was recorded by hand-held stopwatch. In the dual-task condition, participants walked 10 meters while producing words which started with letter "K".[24]

TUG Test is an easy test used to evaluate mobility.[24] The time required to stand up from a chair, walk 3 m to the line on the floor at a comfortable speed, walk back to the chair and sit down is measured. Scores of 13.5 seconds or more suggest that the person may be prone to falling.[22]

Tinetti's Falls Efficacy Scale (FES), that was used to evaluate fall-related self-efficacy, is a 10-questions scale.[25] The effect of fear of falls on a person's confidence to carry out daily living activities is assessed by FES. Participants rate each question with a score ranging from 0 to 10. The sum of the scores gives a total score between 0 (low fall-related self-efficacy) and 100 (high fall-related self-efficacy).

The Berg Balance Scale (BBS) includes 14 balance related tasks that evaluate the static, dynamic, and functional balance skills.[26] The success of each task was evaluated using a scoring scale between "0" (unable) and "4" (independent). The sum of all scores was recorded. The scores between 0-20, 21-40, 41-56 indicate dependent, at risk of falling and independent respectively.[26]

By using the website www.randomizer.org, participants were randomly allocated to three intervention groups training three times a week for four weeks and followed by the same seven years experienced physiotherapist: 1) Single-task group (1st Group; n=15) performed 30 minutes of single-task balance and gait exercises 2) dual-task group (2nd Group; n=15) performed 30 minutes of cognitive activities simultaneously with balance and gait exercise and 3) the successive physical-cognitive training group (3rd Group; n=15) performed 30 minutes of cognitive activities, followed by 5 minutes of rest and 30 minutes of balance and gait exercises (Figure 1).

Participants received one by one training sessions in the university research laboratory of Istanbul Medipol University. For all intervention groups, the balance and gait exercises were chosen from the exercises that have been shown to be effective in improving balance and dual-task performance.[27] The program included static and dynamic balance exercises. The participants in single-task training received 30 minutes single-task balance and gait exercises, 3 times a week for 4 weeks.

Static balance exercises were given as following:

- Body stability
- Standing legs apart and together
- Standing with eyes closed
- Tandem standing

- Standing on foam surface
- One leg standing
- Standing while throwing and catching a ball
- Forward and backward weight shifting
- Keeping standing position while being disturbed by external perturbation.

Dynamic balance exercises included:

- Tandem walking
- Walking in different direction (backward, side to side),
- Transfer activities (from 1 chair to another)
- Sit to stand 5 times.

During the cognitive activities, participants in dual-task and successive physical-cognitive training groups performed 1) visual attention tasks: participants were asked to a- find certain figures and/or words on a paper which is filled with figures and/or words, b- find the seven differences between two pictures and c- name the color of the ink in which an incompatible color word is printed (e.g., to name "blue" in response to word *yellow* printed in blue ink), 2) auditory attention tasks: participants were asked to discriminate logically inappropriate words or phrases in the sentences presented orally, 3) planning tasks: putting days of the week, letters of the alphabet in a consecutive order and/or putting sequences of events in a logical order to form a coherent story, 4) verbal fluency with categorical and phonological constraints, 5) simple mental math activities (addition and subtraction of two-digit numbers) and 6) maze activities. These cognitive activities were chosen as previous work demonstrated their relevance to executive functions.[28] The participants in the successive physical-cognitive training group performed 30 minutes of cognitive activities and the participants in the dual-task group performed 30 minutes of cognitive activities simultaneously with balance and gait exercises.

Statistical analysis

The statistical analyses were carried out using IBM SPSS Statistics software, version 20 (SPSS, Chicago, IL, USA). The Shapiro-Wilk test was used to assess compliance with the normal distribution of the data obtained in the study. The training effect on gait speed, BBS and TUG among the groups was measured using one-way ANOVA where the difference between post and pretraining scores was taken as a factor. Post-hoc LSD tests were performed for determination of significant differences between Groups 1 and 2; between Groups 1 and 3 and between Groups 2 and 3. Kruskal Wallis test was used to measure the training effects on FES among the groups. Bonferroni corrected Mann-Whitney U test was used to measure the effects of training on FES between Groups 1 and 2; between Groups 1 and 3 and between Groups 2 and 3. The comparison of outcome measurements between baseline and post-intervention for each group was examined by Student's paired t test (gait speed, BBS and TUG) and Wilcoxon tests (FES). The level of significance was set at $p=0.017$ for Bonferroni corrected Mann-Whitney U test and $p=0.05$ for paired Student's t test.

Post-hoc analysis was carried out using G*Power software version 3.1.9.6 (University of Kiel, Kiel, Germany). Power analysis indicated the power=0.63 for the large effect size.

RESULTS

A total of 45 healthy older adults participated in the present study (Table 1). We found a significant improvement in gait speed under ST condition in all intervention groups (paired t-test, $p<0.05$) (Table 2). However, participants who received successive physical-cognitive training and dual-task training had greater reduction in gait speed under single-task condition compared to participants in single-task training groups ($p<0.05$). The results showed that gait speed under dual-task condition was significantly improved in the groups receiving cognitive activity training ($p<0.05$) (Table 2). However, no significant difference in gait speed under dual-task condition was found between the participants who received dual-task training and successive physical-cognitive training ($p>0.05$) (Table 2).

We found a significant decrease at TUG time in all intervention groups ($p<0.05$) (Table 2). Participants who received successive physical-cognitive training had greater reduction in TUG compared to participants in single-task and dual-task training groups ($p<0.05$) (Table 3). There was an increase in FES for participants in single-task training and participants in successive physical-cognitive training ($p<0.05$) which is indicative of greater self-efficacy (Table 2). However, FES scores of participants who received successive physical-cognitive training was significantly higher than participants who received single-task training ($p<0.017$) (Table 3). BBS score increased in all intervention groups which is indicative of improvement in balance ($p<0.05$) (Table 2). Participants who received successive physical-cognitive training and single-task training had a greater increase in BBS compared to dual-task training ($p<0.05$) (Table 3). However, participants in successive physical-cognitive training group had a greater increase in BBS compared to single-task training.

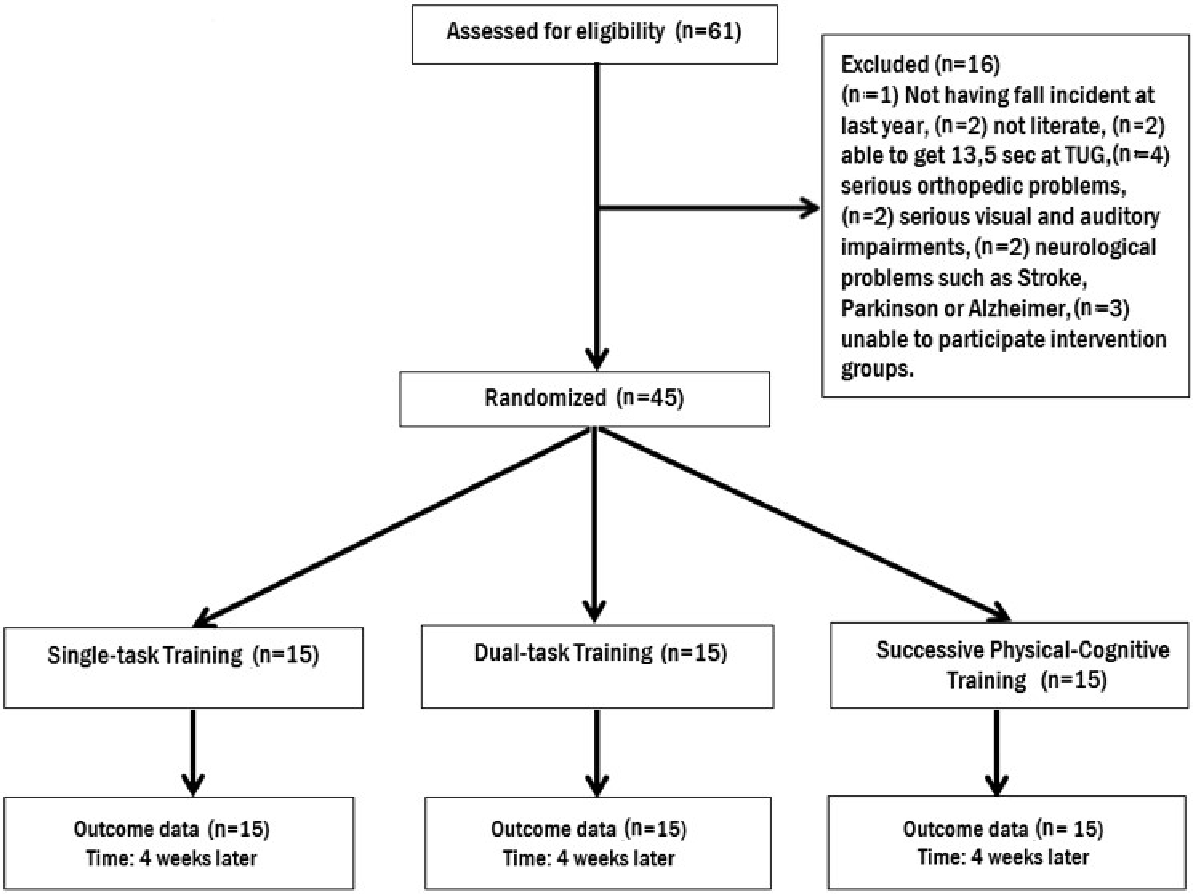

Figure 1. The flow chart of the study participants.

Table 1. Baseline characteristics for all groups.

	Group 1 (n=15)	Group 2 (n=15)	Group 3 (n =15)	
Gender (Female/Male) (n)	13/2	13/2	13/2	
	Mean (SD)	Mean (SD)	Mean (SD)	p
Age (year)	71.8 (4.1)	69.0 (5.1)	71.3 (4.2)	0.169
Body Mass Index (kg/m^2)	26.8 (1.9)	25.5 (1.8)	26.1 (3.0)	0.643
Standardized Mini-Mental State Examination	26.8 (1.6)	26.9 (1.3)	26.0 (1.0)	0.283

Group 1: Single Task Training Group; Group 2: Dual Task Training Group; Group 3: Successive Physical-Cognitive Training Group.

Table 2. Baseline and post training outcome measures for all groups.

	Group 1 (n =15)		Group 2 (n =15)		Group 3 (n =15)	
	Baseline Mean (SD)	Post-train. Mean (SD)	Baseline Mean (SD)	Post-train. Mean (SD)	Baseline Mean (SD)	Post-train. Mean (SD)
Timed Up and Go Test (sec) (b)	15.3 (1.7)	13.2 (1.5)*	14.7 (1.7)	12.7 (1.2)*	16.07 (2.3)	12.1 (1.3)*
Fall Efficacy Scale (a)	79.2 (4.7)	80.0 (4.8)*	83.2 (5.3)	83.6 (4.9)	76.7 (6.3)	81.4 (6.2)*
Berg Balance Score (b)	49.0 (2.0)	50.7 (2.3)*	50.9 (2.4)	51.5 (1.9)*	49.4 (2.8)	51.8 (2.8)*
Single Task gait speed (m/s) (b)	0.78 (0.05)	0.8 (0.04)*	0.77 (0.06)	0.8 (0.07)*	0.76 (0.06)	0.9 (0.08)*
Dual Task gait speed (m/s) (b)	0.63 (0.04)	0.6 (0.05)	0.64 (0.04)	0.7 (0.06)*	0.62 (0.04)	0.7 (0.05)*

*p<0.05, between baseline and post training. a: Wilcoxon Signed Rank Test. b: Paired t Test.
Group 1: Single Task Training Group. Group 2: Dual Task Training Group. Group 3: Successive Physical-Cognitive Training Group.

Table 3. Changes between baseline and post training scores for all groups.

	Group 1 (n =15)	Group 2 (n =15)	Group 3 (n =15)	p
	Mean (SD)	Mean (SD)	Mean (SD)	
Timed Up and Go Test (sec) (b)	-2.1 (0.9)	-2.0 (0.8)	-3.9 (2.5)	0.004*
Fall Efficacy Scale (a)	0.8 (1.2)	0.4 (1.1)	4.7 (5.5)	<0.001
Berg Balance Score (b)	1.7 (1.2)	0.6 (1.0)	2.4 (1.6)	0.002*
Single Task gait speed (m/s) (b)	0.03 (0.04)	0.06 (0.05)	0.1 (0.09)	<0.001*
Dual Task gait speed (m/s) (b)	-0.002 (0.02)	0.08 (0.05)	0.1 (0.05)	<0.001*

*p<0.05. a: Kruskal Wallis Test. b: One way ANOVA.
Group 1: Single Task Training Group; Group 2: Dual Task Training Group; Group 3: Successive Physical-Cognitive Training Group.

Table 4. Comparison of the effects of training (differences of post-pre intervention scores) between the 1st and 2nd; between 1st and 3rd and between 2nd and 3rd groups.

		p
Timed Up and Go Test (TUG) (b)	Group 1-Group 2	0.975
	Group 1-Group 3	0.058
	Group 2-Group 3	0.039*
Fall Efficacy Scale (FES) (a)	Group 1-Group 2	0.344
	Group 1-Group 3	0.001*
	Group 2-Group 3	<0.001
Berg Balance Score (BBS) (b)	Group 1-Group 2	0.062
	Group 1-Group 3	0.296
	Group 2-Group 3	0.001*
Single-task gait speed (b)	Group 1-Group 2	<0.001
	Group 1-Group 3	<0.001
	Group 2-Group 3	0.268
Dual-task gait speed (b)	Group 1-Group 2	<0.001
	Group 1-Group 3	<0.001
	Group 2-Group 3	0.114

*p<0.05. a: Bonferroni corrected Mann-Whitney U test, p<0.017. b: Post-hoc LSD test.

DISCUSSION

In this study, we investigated the effect of three different training programs on balance, gait performances and fall risk for healthy elderly people at risk of fall. The interventions were single-task training, dual-task training, and successive physical-cognitive training. All interventions improved balance skills and gait performances and were effective in reducing fall risk in older adults. Our results indicate that an intervention strategy involving cognitive and physical activities results in better improvement in gait speed under single-task and dual-task conditions when compared to single-task training. However, our outcome measures related to fall efficacy (FES) and balance (BBS) indicated a significant difference in improvement between dual-task training and successive physical-cognitive training groups. While outcome measures related to gait speed have not demonstrated a significant difference between the dual-task training and successive physical-cognitive training groups, the statistically significant difference in improvements for TUG, FES and BBS scores between these two groups still suggest that successive cognitive-physical training may be more effective in improving balance skills, gait speed and reducing fall risk than the other two training strategies.

The TUG and BBS tests are frequently used to determine balance performance and functional ability in the elderly. In the recent studies, it has been demonstrated that TUG could be used to screen recurrent falls in community-dwelling elderly and to determine the risk of falls among the older adults with hip fractures.[29,30] Shumway-Cook et al.[31] showed that each one-point reduction at the BBS scores corresponds to an increase of fall risk among individuals who obtained between 46-54 points. In our study, participants increased their BBS scores by one point after single-task training, one point after dual-task training and two points after successive physical-cognitive training suggesting a 6-8%, 6-8% and a 12-16% decrease in the risk of fall, respectively. All individuals reduced their TUG time scores less than 13.5 seconds; a suggested cut-off point for the risk of fall in elderly.[32]

Present study indicated the improvement in the BBS scores was superior in the successive physical-cognitive training group when compared with the dual-task and single-task training groups. The reason of no significant differences after the dual-task training when compared to the single-task training may be that the participants had higher BBS scores in the pre-intervention. BBS which has been often considered as a 'gold standard' for the assessment of balance performances, has limitations especially during the measurement of dynamic balance performances.[33] The increase of physically active older adults who perform more physical activity in the daily routine indicates a need for scales with more balance demanding items.[34] Previous studies in the community-dwelling older adults reported a high ceiling effect in the BBS.[35] Although there was no heterogeneity among the groups according to the age and BMI of the participants in the present study, the participants that in the dual-task training group was younger and has less BMI, when compared to the successive physical-cognitive training and single-task training groups. The reason for the high pre-intervention BBS scores in the dual-task training group may be that the participants in the dual-task training group was more physically active. Therefore, it is recommended to future studies to recruit the participants according to their physical activity levels.

Fear of falling is a modifiable risk factor for falls and can be positively influenced through physical activity and exercise interventions.[36] In the present study, the FES scores indicate that participants in the successive physical-cognitive training group felt least worried about the possibility of falling. Previous studies showed that balance-specific dual-task training, and exercise interventions may decrease fear of fall and enhance balance confidence.[37,38] In our results, the fact that fear of falling did not have a statistically significant change after dual-task training is worth notice. One statement for no significant differences after the dual-task intervention may be that the participants already had high scores at pre-intervention, hence the improvement potential was low. The subjects of dual-task training group had higher FES scores in the pre-intervention period. Their ability to improve FES might be more limited as their initial scores were already high, so the results may indicate a ceiling effect which was reported from previous studies for this scale.[39]

Therefore, we could not conclude that the efficacy of dual-task training was less for improving FES in older people.

Gait speed is a good indicator of fall risk in older adults.[6] We found an increase in gait speed under single-task condition in all intervention groups. However, dual-task training and successive physical-cognitive training were found to be more effective than single-task training in improving gait speed under single-task condition. Previous findings have demonstrated that walking is not merely a rhythmic and automated process, but also demands attention.[40,41] During walking, the limited cognitive resources attributed to balance control may result in a decrease in spontaneous gait speed. Although spontaneous walking requires less cognitive resources than dual-task walking, increasing number of studies have demonstrated that spontaneous gait in older adults is not simply an automatic process.[42,43] Previous studies demonstrated a relevance between decline in executive function and slower spontaneous gait speed in healthy older people.[40,41] In the current study, dual-task training and successive physical-cognitive training groups performed cognitive activities which possibly activated the brain regions responsible for executive functions. The higher improvements in gait speed under single-task condition for dual-task training and successive physical-cognitive training groups might be related to the possible improvement in executive functions induced by cognitive exercises.

Gait speed slower than 1 m/s is associated with morbidity and mortality.[44] In our study, all participants walked slower than 1 m/s at pre-intervention and at the post-intervention. However, gait speed under single-task and dual-task conditions of the dual-task training group and successive physical-cognitive training group increased by 0.06 m/s and 0.09 m/s and 0.18 m/s and 0.12 m/s respectively. Also, previous study has demonstrated that an improvement of 0.10 m/s in gait speed under single-task condition is considered a meaningful change in elderly.[6] This may suggest that successive physical-cognitive training is more beneficial in decreasing mortality risk in elderly.

Motor learning relies on the premise that training by frequent repetitions of task-specific exercises improves task performance.[45] According to previous studies, efficient coordination and integration between the two tasks is important for improving dual-task performance.[27] A recent systematic review and meta-analysis demonstrated that dual-task training is more effective in improving gait speed under dual-task conditions in the older adults when compared to single-task training.[15] Especially dual-task training consisting of cognitive and motor activity has a positive additional effect on fall frequency due to improvement in gait initiation, dual-task costs of walking and divided attention.[17] Our findings showed that both dual-task training and successive physical-cognitive training programs were more effective than single-task training at improving gait speed under dual-task condition. These findings suggested that adding cognitive activities to training programs could be an effective strategy for improving gait speed under dual-task condition. However, no statistical difference was found between dual-task training and successive physical-cognitive training in improving dual-task walking speed. Ruthruff et al.[19] showed that practicing single task at a time allows participants to automate the performance of individual tasks, which results in a decrease in the demand required to perform each task. Also, previous animal studies showed that physical exercise promotes formation of neurons in the brain[20] while cognitive training modulates synaptic formation between these new neurons.[21] The improvement in the survival of exercise-induced neurons with exposure to exercise and cognitive activities sequentially and automatization of each task may explain the increase in gait speed under dual-task after successive physical-cognitive training.

Silsupadol et al.[27] compared single-task training and dual-task training on balance performance in older adults. Participants were randomly assigned to balance training under single-task conditions or balance training under dual-task conditions with either fixed priority instructions (equal attention to posture and cognitive tasks) or variable priority instructions (attention switched between posture and cognitive task). All three interventions improved gait speed under single-task conditions and decreased the risk of fall. However, only the dual-task training group improved gait speed under dual-task condition. In the current study, participants were asked to give equal attention to posture and cognitive tasks while performing dual-task training. Participants performing successive physical-cognitive training demonstrated more significant improvement in gait speed under dual-task conditions and fall risk than dual-task training. Data from previous studies support the idea that training-related changes in the risk of fall can be explained by increased automating the motor tasks, neurogenesis, postural control and executive functions.[19-21]

Limitations

The following limitations need to be acknowledged. First, sample size in each group (n=15) is small; thus, we do interpret the results with caution. In this sense, the analyses are quite exploratory, and the hypothesis needs to be confirmed with studies involving higher number of participants, hence evidence with more powerful statistics will be sought in future work. Secondly, the most of the participants in the study were women which makes our sample population slightly biased to make inferences about the general population. Thirdly, the amount of improvement that we can see in successive physical-cognitive training could be the consequence of receiving a longer duration of treatment (60 minutes) compared to single-task training and dual-task training groups (30 minutes intervention). Last, the duration of intervention was short. Application of the same dose of training on homogeneous groups and a larger population of participants will be the scope of future research.

Conclusion

In conclusion, the findings of the present study suggest that an intervention strategy involving cognitive and physical activities results in better improvement for gait speed than interventions involving physical activities alone. However, successive physical-cognitive training may be more effective in improving balance skills and reducing fear of fall in elderly, which are prominent risk factors of fall. This study may constitute a reference for future studies in the topic of fall prevention in older adults. Future studies are required to investigate whether these improvements remain valid in studies designed with larger and more homogenous sample groups of participants.

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