COMBINED TRAINING'S EFFECTS ON ELDERLY PEOPLE'S DEVELOPMENT TO MINIMIZE RISK OF FALLING

Warawoot Chuangchai
Department of Medical Engineering, Faculty of Engineering, Thammasat University, Thailand

Yongyuth Siripakarn
Department of Orthopaedics, Faculty of Medicine, Thammasat University, Thailand

Abstract

Falls are the leading issue threatening the elderly persons' well-being. The cause of falls is concerned with cognitive and motor dysfunctions which greatly impact the daily lives of the elderly people. With such awareness, the present study reviews the effects of combined training intervention that can improve cognitive and motor plasticity. The elderly fallers (n = 14), and the elderly non-fallers (n = 14) aged 62 - 85 years old participated in this study. The combined training sessions covered 8 levels of Stroop test and practice as well as 8 sessions of ball juggling. The difficulty of both types of training continued to increase each week. Pretest, mid-test, and posttest data derived from the participants were examined along these 8-week activities. For participant characteristics, significant differences of the elderly fallers were found at pretest, mid-test, and posttest in the category of time spent with all answers on the left hand in finger-nose test, time spent with all answers on the right hand in finger-nose test, weight, and body mass index (P = 0.001, P = 0.007, P = 0.022, and P = 0.022 respectively). For the elderly non-fallers, differences were found in the category of time spent with all answers on the left hand in finger-nose test, time spent with all answers on the right hand in finger-nose test, weight, body mass index, and the 6-minute walk test in diastolic blood pressure at rest (P < 0.001, P = 0.002, P = 0.012, P = 0.013, and P = 0.023 respectively). The present study therefore suggests the benefits of combined training that could empower cognitive and motor plasticity to finally help reduce risks of falling among elderly persons.

Keywords: Combined training, Cognitive plasticity, Motor plasticity, Elderly people, Falls

1. Introduction

Most societies worldwide recognize the pressing clinical issue regarding falls and fall-related injuries which occurs to the elderly population (Rubenstein, 2006). For aging people, nonfatal fall injuries may lead to increase in morbidity, decline in functioning ability (Davis et al., 2015) as well as excessive requirement for healthcare resources (Hartholt et al., 2011). Meanwhile, cognitive and motor degeneration have been found to play an important role in falls (Barban et al., 2017). Also, several previous studies indicated that a combination of exercises could be a prevention strategy to tackle fall problems (Gschwind et al., 2013; Karinkanta, Kannus, Uusi-Rasi, Heinonen, & Sievänen, 2015; Segev-Jacubovski et al., 2011). With these notions, Stroop and ball juggling could be a potential answer for a combination of training to obstruct falls since they are regarded as practicing methods for cognitive and motor plasticity for elderly persons (Boyke, Driemeyer, Gaser, Buchel, & May, 2008; Davidson, Zacks, & Williams, 2003; Voelcker-Rehage, 2008). These 2 kinds of practicing activities could be a new practical way of combined intervention which had not taken place in any early studies. The purpose of the present study then is to determine the effects of cognitive and motor plasticity trainings in elderly persons through fall-related factors such as exercise capacity (Bautmans, Lambert, & Mets, 2004), visual ability (Lord, 2006), dynamic of body movement coordination, static joint of foot position sense (Suetterlin & Sayer, 2014), and tactile perception of foot ability (Itshak Melzer, Benjuya, Kaplanski, & Alexander, 2009).

2. Materials and methods

2.1 Participants

The present study recruited and selected male and female participants from Watsanawet social welfare development center for elderly persons located in Phra Nakhon Si Ayutthaya province of Thailand. This study comprised 28 participants aged 62 - 85 years old. The previous 12 months of medical records or official reports were used to divide participants into 2 groups. One or more times of falls made a group of the elderly fallers. A group of the elderly non-fallers were those who had no record of falls. The selection criteria included the age of 60 years or older, the ability to walk for 6 minutes without any helping equipment or support (Steffen, Hacker, & Mollinger, 2002), the score of Thai mini mental state examination at 24 or above (Ramirez, Wood, Becho, Owings, & Espino, 2010), and most importantly the lack of prior experience in juggling. The unqualified applicants were those who were not capable of comprehending the study purpose and not available at the training for more than 1 day. Those having a record of severe psychological, psychiatric problems, neurological disorders (Swanenburg, de Bruin, Uebelhart, & Mulder, 2010) as well as motor cognitive restriction such as Stroke and Parkinson's disease (Voelcker-Rehage & Willimczik, 2006) were too not eligible. Interviews in the topics of overall health and background were conducted and collected to confirm eligibility status. The participants were given their written and informed consent to join the present study which was approved by the local ethical committee, Faculty of Medicine, Thammasat University (MTU-EC-DS-6-069/59) in the final stage.

2.2 Measurements

Measurement of the present study was carried out with pretest, mid-test, and posttest data. Weight and height of the participants were measured for body mass index calculation. For the 6-minute walk test (Camarri, Eastwood, Cecins, Thompson, & Jenkins, 2006), heart rate at rest (systolic blood pressure at rest and diastolic blood pressure at rest), and distance were measured to calculate velocity, $VO_{2\ max}$, and metabolic equivalent time. Visual acuity test was examined with Landolt ring chart (Kulmala et al., 2009) to determine the eye ability both when the participants were with and without their own glasses. A proprioceptive sense was measured in both dynamic and static positions (Suetterlin & Sayer, 2014). Finger–nose test was used to evaluate the dynamic movement of coordination and toe position sense was for testing in static joint position sense. Two-point discrimination test was measured in metatarsal (Toledo & Barela, 2010) and toe areas of foot to detect the tactile perception ability (I. Melzer, Benjuya, & Kaplanski, 2004).

2.3 Combined plasticity training

The combined training in this present study consisted of 2 forms. First, Stroop was used for cognitive plasticity training. Stroop application in Thai language comprised 8 levels and the data retrieved from the application was collected through tablet device. Participants were asked to respond as quickly and accurately as they could in congruent and incongruent settings of the tests with a changing combination of colors, words and background offering dynamic pattern of questions. Participants reacted to the test by reaching red, yellow, green, or blue colors on the screen. Methodically the training took place 10 times a day and ran every day except on weekends.

Second, juggling activity was used for motor plasticity training. Participants were asked to systematically learn juggling with 3 standard tennis balls. Eight sessions of practice started with 1 ball and continuously the difficulty increased to up to 3 balls. Juggling practice covered different sessions with 1 session being trained weekly. From session 1 to session 4, simple tasks were covered. Dual tasks were on session 5 to session 8 with participants tramping on pebble wash tiles barefoot while doing juggling. The practice was performed for 30 minutes every day except on weekends.

2.4 Statistical analysis

Differences between the elderly fallers and the elderly non-fallers (Table 1 - 3) were analyzed and compared with the Independent (unpaired) *t*-test. All differences among pretest, mid-test, and posttest (Table 4 and Table 5) stages were analyzed and compared with repeated ANOVA except the comparison of differences between pretest and posttest in two-point discrimination test, which was analyzed only with a paired *t*-test. All variables were presented as mean with standard deviation (± SD). All analyses were considered with statistical significance determined at *P* value of < 0.05.

3. Results

Firstly, the basis data of participant characteristics at pretest stage demonstrated significant differences between 2 groups in the category of visual acuity test on the left side, number of incorrect answer on the right hand in finger-nose test, weight, body mass index, and time spent with all answers on the right hand in finger-nose test (P = 0.006, P = 0.008, P = 0.014, P = 0.019, and P = 0.039 respectively). In contrast, no significant differences were found between 2 groups in the category of the 6-minute walk test, visual acuity test on the right side, visual acuity test on the right side with glasses, visual acuity test on the left side with glasses, number of incorrect answer on the left hand in finger-nose test, time spent with all answers on the left hand in finger-nose test, toe position sense test, and two-point discrimination test (Table 1).

Table 1. Comparison of participant characteristics between the elderly fallers and the elderly non-fallers at pretest

Pretest	**Elderly fallers (±SD)** n **= 14**	**Elderly non-fallers (±SD)** n **= 14**	P **value**
Weight (kg)	50.19 (±7.12)	57.15 (±6.81)	**0.014***
Body mass index (kg/m^2)	21.41 (±2.31)	23.92 (±2.95)	**0.019***
The 6-minute walk test			
Rest heart rate (bpm)	80.50 (±8.87)	75.93 (±6.29)	0.128
Rest systolic blood pressure (mm Hg)	147.21 (±14.57)	145.71 (±20.25)	0.824
Rest diastolic blood pressure (mm Hg)	68.79 (±10.29)	73.14 (±10.44)	0.276
Distance (meters)	376.66 (±72.58)	379.95 (±91.67)	0.917
Velocity (m/min)	62.78 (±12.10)	63.33 (±15.28)	0.917
$VO_{2\ max}$ (ml/kg^{-1}/min^{-1})	30.29 (±3.56)	29.41 (±2.78)	0.473
Metabolic equivalent time	2.79 (±0.35)	2.80 (±0.44)	0.917
Visual acuity (decimal notation)			
Right side	0.16 (±0.22)	0.28 (±0.17)	0.116
Left side	0.12 (±0.13)	0.31 (±0.20)	**0.006***
Right side with glasses	0.21 (±0.23)	0.33 (±0.17)	0.307
Left side with glasses	0.17 (±0.22)	0.30 (±0.23)	0.309
Finger-nose test			
Number of incorrect answer on the right hand	0.93 (±0.92)	0.14 (±0.36)	**0.008***
Time spent with all answers on the right hand (second)	15.63 (±4.85)	12.30 (±3.11)	**0.039***
Number of incorrect answer on the left hand	0.43 (±0.65)	0.21 (±0.58)	0.364
Time spent with all answers on the left hand (second)	14.74 (±4.40)	12.12 (±3.35)	0.088
Toe position sense			
Number of incorrect answer on the right foot	0.43 (±1.09)	0.43 (±1.09)	1.000
Number of incorrect answer on the left foot	0.36 (±0.63)	0.29 (±0.83)	0.799
Two-point discrimination (mm)			
Metatarsal of the right foot	29.79 (±11.68)	25.93 (±7.63)	0.310
Metatarsal of the left foot	31.21 (±14.79)	30.43 (±10.90)	0.874

Toe of the right foot	18.64 (±5.93)	21.21 (±5.56)	0.247
Toe of the left foot	19.93 (±5.72)	22.14 (±5.53)	0.307

* Significant at $P < 0.05$

Table 2. Comparison of participant characteristics between the elderly fallers and the elderly non-fallers at mid-test

Mid-test	**Elderly fallers (±SD)** ***n* = 14**	**Elderly non-fallers (±SD)** ***n* = 14**	***P* value**
Weight (kg)	49.23 (±6.72)	56.28 (±7.03)	**0.012***
Body mass index (kg/m^2)	21.02 (±2.36)	23.56 (±3.12)	**0.022***
The 6-minute walk test			
Rest heart rate (bpm)	80.71 (±10.48)	73.36 (±8.32)	**0.050***
Rest systolic blood pressure (mm Hg)	149.71 (±14.64)	138.29 (±20.57)	0.102
Rest diastolic blood pressure (mm Hg)	71.79 (±8.97)	67.79 (±8.83)	0.245
Distance (meters)	363.87 (±75.29)	384.41 (±77.73)	0.484
Velocity (m/min)	60.65 (±12.55)	64.07 (±12.95)	0.484
$VO_{2\ max}$ ($ml/kg^{-1}/min^{-1}$)	30.22 (±3.88)	30.25 (±2.21)	0.977
Metabolic equivalent time	2.73 (±0.36)	2.83 (±0.37)	0.484
Visual acuity (decimal notation)			
Right side	0.18 (±0.26)	0.29 (±0.15)	0.191
Left side	0.12 (±0.16)	0.31 (±0.20)	**0.008***
Right side with glasses	0.23 (±0.21)	0.39 (±0.17)	0.152
Left side with glasses	0.20 (±0.21)	0.37 (±0.21)	0.154
Finger-nose test			
Number of incorrect answer on the right hand	0.29 (±0.61)	0.14 (±0.36)	0.459
Time spent with all answers on the right hand (second)	14.74 (±5.51)	8.82 (±2.24)	**0.002***
Number of incorrect answer on the left hand	0.36 (±0.63)	0.71 (±0.83)	0.210
Time spent with all answers on the left hand (second)	10.17 (±2.12)	7.81 (±2.36)	**0.010***
Toe position sense			
Number of incorrect answer on the right foot	0.21 (±0.42)	0.14 (±0.36)	0.637
Number of incorrect answer on the left foot	0.07 (±0.27)	0.21 (±0.43)	0.299

* Significant at $P < 0.05$

Secondly, the intermediate data of participant characteristics at mid-test presented significant differences between 2 groups in the category of time spent with all answers on the right hand in finger-nose test, visual acuity test on the left side, time spent with all answers on the left hand in finger-nose test, weight, body mass index, and the 6-minute walk test in heart rate at rest aspect ($P = 0.002$, $P = 0.008$, $P = 0.010$, $P = 0.012$, $P = 0.022$, and $P = 0.050$ respectively). In contrast, no significant differences were identified between 2 groups in the category of the 6-minute walk test including systolic blood pressure at rest, diastolic blood pressure at rest, distance, velocity, $VO_{2\ max}$, and metabolic equivalent time, and in the category of visual acuity test on the right side, visual acuity test on the right side with glasses, visual acuity test on the left side with glasses, number of incorrect answer on the right hand in finger-nose test, number of incorrect answer on the left hand in finger-nose test as well as toe position sense test (Table 2).

Table 3. Comparison of participant characteristics between the elderly fallers and the elderly non-fallers at posttest

Posttest	**Elderly fallers (±SD)** ***n* = 14**	**Elderly non-fallers (±SD)** ***n* = 14**	***P* value**
Weight (kg)	49.34 (±6.72)	27.19 (±7.19)	**0.006***
Body mass index (kg/m^2)	21.06 (±2.27)	23.94 (±3.17)	**0.010***
The 6-minute walk test			
Rest heart rate (bpm)	83.07 (±11.21)	75.14 (±8.54)	**0.045***
Rest systolic blood pressure (mm Hg)	152.93 (±14.34)	140.86 (±18.07)	0.061
Rest diastolic blood pressure (mm Hg)	73.21 (±9.86)	72.07 (±12.41)	0.789
Distance (meters)	390.44 (±57.69)	389.08 (±88.60)	0.962
Velocity (m/min)	65.07 (±9.61)	64.85 (±14.77)	0.962
$VO_{2\ max}$ (ml/kg^{-1}/min^{-1})	30.34 (±3.92)	29.76 (±2.60)	0.644
Metabolic equivalent time	2.86 (±0.27)	2.85 (±0.42)	0.962
Visual acuity (decimal notation)			
Right side	0.20 (±0.24)	0.26 (±0.13)	0.442
Left side	0.12 (±0.13)	0.29 (±0.16)	**0.005***
Right side with glasses	0.24 (±0.25)	0.34 (±0.17)	0.401
Left side with glasses	0.17 (±0.20)	0.31 (±0.25)	0.256
Finger-nose test			
Number of incorrect answer on the right hand	0.43 (±0.76)	0.50 (±0.65)	0.791
Time spent with all answers on the right hand (second)	10.50 (±2.36)	8.44 (±2.60)	**0.037***
Number of incorrect answer on the left hand	0.36 (±0.50)	0.29 (±0.61)	0.737
Time spent with all answers on the left hand (second)	8.22 (±1.82)	6.69 (±1.71)	**0.030***
Toe position sense			
Number of incorrect answer on the right foot	0	0	N/A
Number of incorrect answer on the left foot	0	0	N/A
Two-point discrimination (mm)			
Metatarsal of the right foot	26.50 (±6.77)	24.79 (±4.61)	0.441
Metatarsal of the left foot	25.14 (±7.32)	25.14 (±4.06)	1.000
Toe of the right foot	21.57 (±7.18)	19.86 (±4.07)	0.444
Toe of the left foot	20.71 (±70)	20.57 (±3.61)	0.945

* Significant at $P < 0.05$, N/A = Not available

Thirdly, the hindmost data of participant characteristics at posttest showed significant differences between 2 groups in the category of visual acuity test on the left side, weight, body mass index, time spent with number of incorrect answer on the left hand in finger-nose test, time spent with number of incorrect answer on the right hand in finger-nose test, and the 6-minute walk test in the area of heart rate at rest (P = 0.005, P = 0.006, P = 0.010, P = 0.030, P = 0.037, P = 0.045 respectively). In contrast, no significant differences were found between 2 groups in the category of the 6-minute walk test including systolic blood pressure at rest, diastolic blood pressure at rest, distance, velocity, $VO_{2\ max}$, and metabolic equivalent time, in visual acuity test on the right side, visual acuity test on the left side, visual acuity test on the left side with glasses, number of incorrect answer on the right hand in finger-nose test, number of incorrect answer on the left hand in finger-nose test, in toe position sense test as well as two-point discrimination test (Table 3).

Table 4. Comparison of the elderly fallers' characteristics at pretest, mid-test, and posttest

Elderly fallers *n* **= 14**	**Pretest (±SD)**	**Mid-test (±SD)**	**Posttest (±SD)**	***P* value**
Weight (kg)	50.19 (±7.12) a, b	49.23 (±6.72) a	49.34 (±6.72) b	**0.022***
Body mass index (kg/m^2)	21.41 (±2.31) c, d	21.02 (±2.36) c	21.06 (±2.27) d	**0.022***
The 6-minute walk test				
Rest heart rate (bpm)	80.50 (±8.87)	80.71 (±10.48)	83.07 (±11.21)	0.636
Rest systolic blood pressure (mm Hg)	147.21 (±14.57)	149.71 (±14.64)	152.93 (±14.34)	0.220
Rest diastolic blood pressure (mm Hg)	68.79 (±10.29)	71.79 (±8.97)	73.21 (±9.86)	0.205
Distance (meters)	376.66 (±72.58)	363.87 (±75.29)	390.44 (±57.69)	0.332
Velocity (m/min)	62.78 (±12.10)	60.65 (±12.55)	65.07 (±9.61)	0.332
$VO_{2\,max}$ ($ml/kg^{-1}/min^{-1}$)	30.29 (±3.56)	30.22 (±3.88)	30.34 (±3.92)	0.977
Metabolic equivalent time	2.79 (±0.35)	2.73 (±0.36)	2.86 (±0.27)	0.332
Visual acuity (decimal notation)				
Right side	0.16 (±0.22)	0.18 (±0.26)	0.20 (±0.24)	0.483
Left side	0.12 (±0.13)	0.12 (±0.16)	0.12 (±0.13)	1.000
Right side with glasses	0.21 (±0.23)	0.23 (±0.21)	0.24 (±0.25)	0.649
Left side with glasses	0.17 (±0.22)	0.20 (±0.21)	0.17 (±0.20)	0.625
Finger-nose test				
Number of incorrect answer on the right hand	0.93 (±0.92)	0.29 (±0.61)	0.43 (±0.76)	0.107
Time spent with all answers on the right hand (second)	15.63 (±4.85) e	14.74 (±5.51) f	10.50 (±2.36) e, f	**0.007***
Number of incorrect answer on the left hand	0.43 (±0.65)	0.36 (±0.63)	0.36 (±0.50)	0.915
Time spent with all answers on the left hand (second)	14.74 (±4.40) g, h	10.17 (±2.12) g, i	8.22 (±1.82) h, i	**0.001***
Toe position sense				
Number of incorrect answer on the right foot	0.43 (±1.09)	0.21 (±0.42)	0	0.103
Number of incorrect answer on the left foot	0.36 (±0.63)	0.07 (±0.27)	0	0.133
Two-point discrimination (mm)				
Metatarsal of the right foot	29.79 (±11.68)	N/A	26.50 (±6.77)	0.234
Metatarsal of the left foot	31.21 (±14.79)	N/A	25.14 (±7.32)	0.102
Toe of the right foot	18.64 (±5.93)	N/A	21.57 (±7.18)	0.082
Toe of the left foot	19.93 (±5.72)	N/A	20.71 (±70)	0.567

* Significant at $P < 0.05$, N/A = Not available

Regarding the elderly fallers' characteristics, significant differences were identified at pretest, mid-test, and posttest in the category of time spent with all answers on the left hand in finger-nose test, time spent with all answers on the right hand in finger-nose test, weight, and body mass index ($P = 0.001$, $P = 0.007$, $P = 0.022$, and $P = 0.022$ respectively). In pairwise comparison, there were significant differences between tests in weight at pretest and mid-test (a; $P = 0.015$), and at pretest and posttest (b; $P = 0.042$), body mass index at pretest and mid-test (c; $P = 0.015$), and at pretest and posttest (d; $P = 0.048$), time spent with all answers on the right hand in finger-nose test at pretest and posttest (e; $P = 0.008$), and at mid-test and posttest (f; $P = 0.037$), time spent with all answers on the left hand in finger-nose test at pretest and mid-test (g; $P = 0.002$), at pretest and posttest (h; $P < 0.001$), and at mid-test and posttest (i; P = 0.042). In contrast, no significant differences were found among tests in the 6-minute walk test, visual acuity test, number of incorrect answer on the right hand in finger-nose test, number of incorrect answer on the left hand in finger-nose test, toe position sense test, and two-point discrimination test (Table 4).

Table 5. Comparison of the elderly non-fallers' characteristics at pretest, mid-test, and posttest

Elderly non-fallers ***n* = 14**	**Pretest (±SD)**	**Mid-test (±SD)**	**Posttest (±SD)**	***P* value**
Weight (kg)	57.15 (±6.81) a	56.28 (±7.03) a	57.19 (±7.19)	**0.012***
Body mass index (kg/m^2)	23.92 (±2.95) b	23.56 (±3.12) b	23.94 (±3.17)	**0.013***
The 6-minute walk test				
Rest heart rate (bpm)	75.93 (±6.29)	73.36 (±8.32)	75.14 (±8.54)	0.326
Rest systolic blood pressure (mm Hg)	145.71 (±20.25)	138.29 (±20.57)	140.86 (±18.07)	0.184
Rest diastolic blood pressure (mm Hg)	73.14 (±10.44)	67.79 (±8.83) c	72.07 (±12.41) c	**0.023***
Distance (meters)	379.95 (±91.67)	384.41 (±77.73)	389.08 (±88.60)	0.774
Velocity (m/min)	63.33 (±15.28)	64.07 (±12.95)	64.85 (±14.77)	0.774
$VO_{2\ max}$ (ml/kg^{-1}/min^{-1})	29.41 (±2.78)	30.25 (±2.21)	29.76 (±2.60)	0.098
Metabolic equivalent time	2.80 (±0.44)	2.83 (±0.37)	2.85 (±0.42)	0.774
Visual acuity (decimal notation)				
Right side	0.28 (±0.17)	0.29 (±0.15)	0.26 (±0.13)	0.615
Left side	0.31 (±0.20)	0.31 (±0.20)	0.29 (±0.16)	0.850
Right side with glasses	0.33 (±0.17)	0.39 (±0.17)	0.34 (±0.17)	0.127
Left side with glasses	0.30 (±0.23)	0.37 (±0.21)	0.31 (±0.25)	0.471
Finger-nose test				
Number of incorrect answer on the right hand	0.14 (±0.36)	0.14 (±0.36)	0.50 (±0.65)	0.254
Time spent with all answers on the right hand (second)	12.30 (±3.11) d, e	8.82 (±2.24) d	8.44 (±2.60) e	**0.002***
Number of incorrect answer on the left hand	0.21 (±0.58)	0.71 (±0.83)	0.29 (±0.61)	0.203
Time spent with all answers on the left hand (second)	12.12 (±3.35) f, g	7.81 (±2.36) f	6.69 (±1.71) g	**< 0.001**
Toe position sense				
Number of incorrect answer on the right foot	0.43 (±1.09)	0.14 (±0.36)	0	0.324
Number of incorrect answer on the left foot	0.29 (±0.83)	0.21 (±0.43)	0	0.235
Two-point discrimination (mm)				
Metatarsal of the right foot	25.93 (±7.63)	N/A	24.79 (±4.61)	0.554
Metatarsal of the left foot	30.43 (±10.90)	N/A	25.14 (±4.06)	0.074
Toe of the right foot	21.21 (±5.56)	N/A	19.86 (±4.07)	0.536
Toe of the left foot	22.14 (±5.53)	N/A	20.57 (±3.61)	0.449

* Significant at $P < 0.05$, N/A = Not available

The elderly non-fallers' characteristics data reflected significant differences among pretest, mid-test, and posttest stages in the category of time spent with all answers on the left hand in finger-nose test, time spent with all answers on the right hand in finger-nose test, weight, body mass index, and the 6-minute walk test in the area of diastolic blood pressure at rest (*P* < 0.001, *P* = 0.002, *P* = 0.012, *P* = 0.013, and *P* = 0.023 respectively). In pairwise comparison, there were significant differences between tests in weight at pretest and mid-test (a; *P* = 0.008), body mass index at pretest and mid-test (b; *P* = 0.010), the 6-minute walk test in the area of diastolic blood pressure at rest at mid-test and posttest (c; *P* = 0.050), time spent with all answers on the right hand in finger-nose test at pretest and mid-test (d; *P* = 0.007), and at pretest and posttest (e; *P* = 0.001), time spent with all answers on the left hand in finger-nose test at pretest and mid-test (f; *P* = 0.006), and at pretest and posttest (g; *P* < 0.001). In contrast, no significant differences were found among tests in the 6-minute walk test in the area of heart rate at rest, systolic blood pressure at rest, distance, velocity, $VO_{2\ max}$, and metabolic equivalent time, in visual acuity test, number of incorrect answer on the right hand in finger-nose test, number of incorrect answer on the left hand in finger nose test, toe position sense test as well as two-point discrimination test (Table 5).

4. Discussion

The results of the present study differentiated the elderly fallers from the elderly non-fallers through weight, body mass index, visual acuity test on the left side, and time spent with all answers on the right hand in finger-nose test (Table 1 - 3). Two groups had continued to reveal some differences in participant characteristics in measurements prior to the training through the end of sessions. Various and dynamic characteristics may affect chances of fall across given situations such as before or after the practice. Thus, perhaps it is a complex dimension of what could lead to falls since a fall could be detected at several stages.

This evidence suggested that weight, body mass index, visual acuity test, and finger-nose test could act as a tool for fall risk assessment in elderly persons. Some past studies such as degree test in proprioception (Schoene, Smith, Davies, Delbaere, & Lord, 2014) and body mass index of participants in Khon Kean of Thailand (Kuhirunyaratn, Prasomrak, & Jindawong, 2013) nonetheless did not discover significant differences between the elderly fallers and the elderly non-fallers.

In a similar way, it was found in the present study that heart rate at rest of the 6-minute walk test and time spent with all answers on the left hand in finger-nose test could separate the elderly fallers from the elderly non-fallers after 4 weeks of training. Heart rate at rest and finger-nose test parameters from mid-test stage to posttest stage were likely to identify the elderly fallers out of the elderly non-fallers. A previous study indicated that differences between orthostatic hypotension and non-orthostatic hypotension in healthy elderly persons gave no significant in heart rate, systolic blood pressure, and diastolic blood pressure (Atli & Keven, 2006). This was well related to the result at baseline in the present study of pretest.

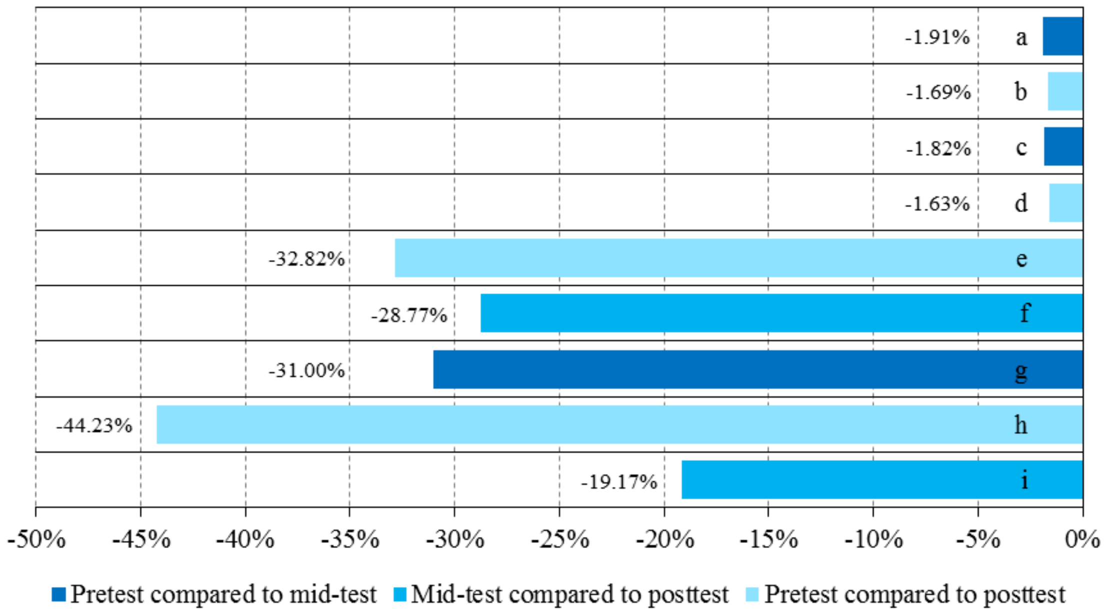

Figure 1. Improvement of the elderly fallers at pretest, mid-test, and posttest

To clarify, the development of the elderly fallers' characteristics in pairwise comparison (Table 4) showed considerable improvements with positive decline in several aspects. Time spent with all answers on the left hand in finger-nose test (h) dropped 44.23%, time spent with all answers on the right hand in finger-nose test (e) dropped 32.82%, time spent with all answers on the left hand in finger-nose test (g) dropped 31.00%, time spent with all answers on the right hand in finger-nose test (f) dropped 28.77%, time spent with all answers on the left hand in finger-nose test (i) dropped 19.17%, weight (a) dropped 1.91%, body mass index (c) dropped 1.82%, weigh (b) dropped 1.69%, and body mass index (d) dropped 1.63% (Figure 1).

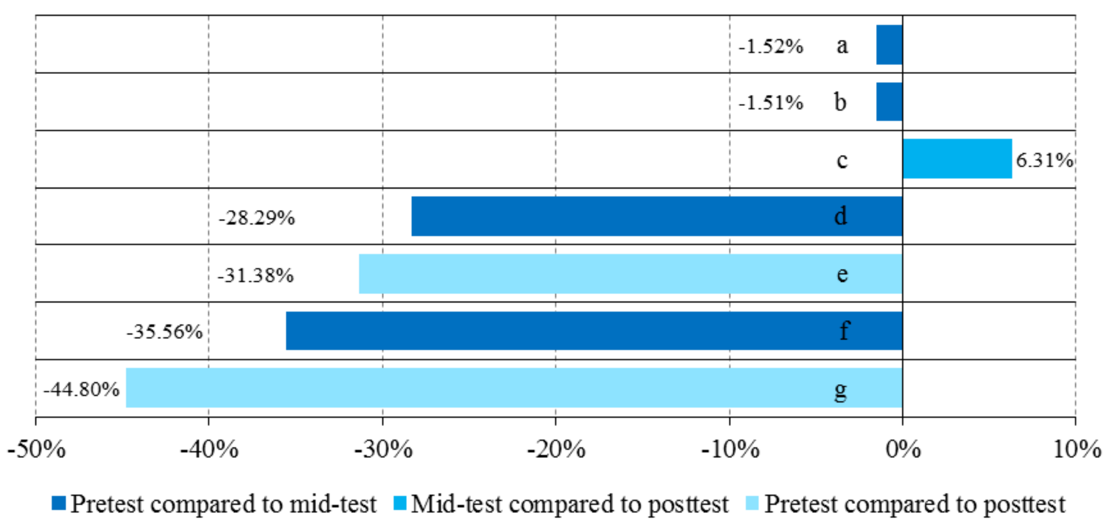

Figure 2. Improvement of the elderly non-fallers at pretest, mid-test, and posttest

The development of the elderly non-fallers' characteristics in pairwise comparison (Table 5) impressively showed significant improvements. Positive decline had been found in several items. Time spent with all answers on the left hand in finger-nose test (g) dropped 44.80%, time spent with all answers on the left hand in finger-nose test (f) dropped 35.56%, time spent with all answers on the right hand in finger-nose test (e) dropped 31.38%, and time spent with all answers on the right hand in finger-nose test (d) dropped 28.29%. The 6-minute walk test in the area of diastolic blood pressure at rest (c) increased 6.31%. Weight (a) fell at 1.51% as well as body mass index (b) which fell at 1.52% (Figure 2).

Interestingly, constructive improvement concerning dynamic of body movement coordination did not happen to only the elderly fallers but also to the elderly non-fallers. Both groups especially the elderly non-fallers showed most development in finger-nose test results. For finger-nose test with the duration of 8 weeks of training from pretest stage to posttest stage, the highest level of improvement was identified among both groups. The elderly fallers took more time of training to show their improvements. For most areas of improvements, they required 8 weeks of training to exhibit effectiveness. Meanwhile, the elderly non-fallers most portrayed their effectiveness in the first phase of 4 weeks. The elderly fallers therefore gained higher frequency of improvements than the elderly non-fallers but the latter group gained the benefits from the combined training more with more convenience and speed (Figure 1 and Figure 2).

The combined training in this present study is not designed for elderly persons only. Such training application should be universal across different ages. The training is not complicated for researchers to organize and also it is user friendly. The budget costs of instruments also make it more possible to reach broader population and perhaps at a country level. These strengths and benefits should take a new approach of combined training to everyday life for everyone, especially the elderly population. Due to time limitation, participant characteristics were not measured after training in the present study. Thus, it is recommended to continue measurements after training to identify length of time where plasticity improvement is still effective in elderly persons. Subjective experiment in relevant falls and cognition issues should also be examined for better comprehension in the section of mental health and psychological wellbeing. More work of research are needed on pre-elderly persons as a study of gap between pre-elderly stage and elderly stage could suggest the most effective moment to introduce combined training. All of these observations should be taken into consideration for future studies.

5. Conclusions

Participant characteristics information obtained from the present study using the combined training of cognitive and motor plasticity could show the difference between the elderly fallers and the elderly non-fallers through the category of weight, body mass index, visual acuity test, and time spent with incorrect answer in finger-nose test. The results may be beneficial as an instrument to evaluate possibility of falls in elderly persons. Evidences at 4 weeks after the training revealed that normal resting heart rate could detect the difference between 2 groups. This supports the concept that the effectiveness of training (Chodzko-Zajko et al., 2009) can influence functioning ability not only in physical aspect but also in cardiovascular system. In comparison with the elderly non-fallers, the elderly fallers gained frequency of improvements from combined training more. However, the elderly non-fallers could receive the training advantages with more ease and better acceleration. The present study provides a novel way of combined training on cognitive and motor plasticity in elderly persons. This training could offer functioning improvements that will contribute greatly as one of potential strategies to minimize chance of falls. This then could ultimately enhance quality of life of the elderly population.

6. Conflicts of interest

None to declare.

7. Acknowledgements

National Science and Technology Development Agency (NSTDA), Ministry of Science and Technology, Thailand provided a grant NSTDA-University-Industry Research Collaboration: NUI-RC (SCA-CO-2559-2530-TH) to support the present study. The authors would like to express thanks to the Eldercare Solution Business of the Siam

Cement Public Company Limited (SCG) for their support on helpful materials and generous collaboration. Also, appreciation should be brought to the Faculty of Medicine, Thammasat University for the research funds and to all officers and participants in the present study for their strong attention. The present study shall also serve as a memorial of the late King Bhumibol Adulyadej of Thailand (Rama IX) for his effort to improve quality of life of the elderly Thai population throughout his time. Some of the results were orally presented at Harvard Faculty Club, Harvard University, Boston, USA, 24 - 27 July 2017 and published in 2017 WEI International Academic Conference Proceedings on Education and Humanities issue.

8. Brief biography

Warawoot Chuangchai is a Ph.D. candidate of Medical Engineering School from Thammasat University, Thailand. Currently he is also a visiting Ph.D. student at Oxford Institute of Population Ageing, University of Oxford. He holds a Master Degree and a Bachelor Degree in Interior Architecture. His professional design credential at Fairmont hotel in Jaipur, India led to several awards including "Best New Hotels of 2013". His design conceptualization does not base on aesthetics only. To give a great purpose by integrating a new perspective of ergonomics into work is also his effort to improve wellness of the elderly population.

Yongyuth Siripakarn, M.D. is a professor in Medical School of Thammasat University, Thailand. He was the president of Medical Organizations and also the director at Thammasat University Hospital. He currently holds the position as member of the board committee at Faculty of Medicine, Thammasat University. His professional concentration is in Orthopedic Surgery with expertise in spine section. He focuses on Sports Medicine Science, and Bioengineering as well.

9. References

Atli, T., & Keven, K. (2006). Orthostatic hypotension in the healthy elderly. *Arch Gerontol Geriatr, 43*(3), 313-317. doi: 10.1016/j.archger.2005.12.001

Barban, F., Annicchiarico, R., Melideo, M., Federici, A., Lombardi, M. G., Giuli, S., . . . Caltagirone, C. (2017). Reducing fall risk with combined motor and cognitive training in elderly fallers. *Brain Sci, 7*(2). doi: 10.3390/brainsci7020019

Bautmans, I., Lambert, M., & Mets, T. (2004). The six-minute walk test in community dwelling elderly: Influence of health status. *BMC Geriatrics, 4*, 6-6. doi: 10.1186/1471-2318-4-6

Boyke, J., Driemeyer, J., Gaser, C., Buchel, C., & May, A. (2008). Training-induced brain structure changes in the elderly. *J Neurosci, 28*(28), 7031-7035. doi: 10.1523/jneurosci.0742-08.2008

Camarri, B., Eastwood, P. R., Cecins, N. M., Thompson, P. J., & Jenkins, S. (2006). Six minute walk distance in healthy subjects aged 55-75 years. *Respir Med, 100*(4), 658-665. doi: 10.1016/j.rmed.2005.08.003

Chodzko-Zajko, W. J., Proctor, D. N., Fiatarone Singh, M. A., Minson, C. T., Nigg, C. R., Salem, G. J., & Skinner, J. S. (2009). American College of Sports Medicine position stand. Exercise and physical activity for older adults. *Med Sci Sports Exerc, 41*(7), 1510-1530. doi: 10.1249/MSS.0b013e3181a0c95c

Davidson, D. J., Zacks, R. T., & Williams, C. C. (2003). Stroop interference, practice, and aging. *Neuropsychol Dev Cogn B Aging Neuropsychol Cogn, 10*(2), 85-98. doi: 10.1076/anec.10.2.85.14463

Davis, J. C., Best, J. R., Bryan, S., Li, L. C., Hsu, C. L., Gomez, C., . . . Liu-Ambrose, T. (2015). Mobility is a key predictor of change in well-being among older adults who experience falls: Evidence from the Vancouver falls prevention clinic cohort. *Arch Phys Med Rehabil, 96*(9), 1634-1640. doi: 10.1016/j.apmr.2015.02.033

Gschwind, Y. J., Kressig, R. W., Lacroix, A., Muehlbauer, T., Pfenninger, B., & Granacher, U. (2013). A best practice fall prevention exercise program to improve balance, strength / power, and psychosocial health in older adults: Study protocol for a randomized controlled trial. *BMC Geriatrics, 13*, 105-105. doi: 10.1186/1471-2318-13-105

Hartholt, K. A., van Beeck, E. F., Polinder, S., van der Velde, N., van Lieshout, E. M. M., Panneman, M. J. M., . . . Patka, P. (2011). Societal consequences of falls in the older population: Injuries, healthcare costs, and long-term reduced quality of life. *Journal of Trauma and Acute Care Surgery, 71*(3), 748-753. doi: 10.1097/TA.0b013e3181f6f5e5

Karinkanta, S., Kannus, P., Uusi-Rasi, K., Heinonen, A., & Sievänen, H. (2015). Combined resistance and balance-jumping exercise reduces older women's injurious falls and fractures: 5-year follow-up study. *Age and Ageing, 44*(5), 784-789. doi: 10.1093/ageing/afv064

Kuhirunyaratn, P., Prasomrak, P., & Jindawong, B. (2013). Factors related to falls among community dwelling elderly. *Southeast Asian J Trop Med Public Health, 44*(5), 906-915.

Kulmala, J., Viljanen, A., Sipilä, S., Pajala, S., Pärssinen, O., Kauppinen, M., . . . Rantanen, T. (2009). Poor vision accompanied with other sensory impairments as a predictor of falls in older women. *Age and Ageing, 38*(2), 162-167. doi: 10.1093/ageing/afn228

Lord, S. R. (2006). Visual risk factors for falls in older people. *Age Ageing, 35 Suppl 2*, ii42-ii45. doi: 10.1093/ageing/afl085

Melzer, I., Benjuya, N., & Kaplanski, J. (2004). Postural stability in the elderly: A comparison between fallers and non-fallers. *Age Ageing, 33*(6), 602-607. doi: 10.1093/ageing/afh218

Melzer, I., Benjuya, N., Kaplanski, J., & Alexander, N. (2009). Association between ankle muscle strength and limit of stability in older adults. *Age and Ageing, 38*(1), 119-123. doi: 10.1093/ageing/afn249

Ramirez, D., Wood, R. C., Becho, J., Owings, K., & Espino, D. V. (2010). Mini-mental state exam domains predict falls in an elderly population: Follow-up from the Hispanic Established Populations for Epidemiologic Studiesof the Elderly (H-EPESE) study. *Ethnicity & disease, 20*(1), 48-52.

Rubenstein, L. Z. (2006). Falls in older people: epidemiology, risk factors and strategies for prevention. *Age and Ageing, 35*(suppl 2), ii37-ii41. doi: 10.1093/ageing/afl084

Schoene, D., Smith, S. T., Davies, T. A., Delbaere, K., & Lord, S. R. (2014). A Stroop Stepping Test (SST) using low-cost computer game technology discriminates between older fallers and non-fallers. *Age Ageing, 43*(2), 285-289. doi: 10.1093/ageing/aft157

Segev-Jacubovski, O., Herman, T., Yogev-Seligmann, G., Mirelman, A., Giladi, N., & Hausdorff, J. M. (2011). The interplay between gait, falls and cognition: Can cognitive therapy reduce fall risk? *Expert review of neurotherapeutics, 11*(7), 1057-1075. doi: 10.1586/ern.11.69

Steffen, T. M., Hacker, T. A., & Mollinger, L. (2002). Age- and gender-related test performance in community-dwelling elderly people: Six-minute walk test, Berg balance scale, timed up & go test, and gait speeds. *Phys Ther, 82*(2), 128-137. doi: 10.1093/ptj/82.2.128

Suetterlin, K. J., & Sayer, A. A. (2014). Proprioception: where are we now? A commentary on clinical assessment, changes across the life course, functional implications and future interventions. *Age and Ageing, 43*(3), 313-318. doi: 10.1093/ageing/aft174

Swanenburg, J., de Bruin, E. D., Uebelhart, D., & Mulder, T. (2010). Falls prediction in elderly people: A 1-year prospective study. *Gait Posture, 31*(3), 317-321. doi: 10.1016/j.gaitpost.2009.11.013

Toledo, D. R., & Barela, J. A. (2010). Sensory and motor differences between young and older adults: Somatosensory contribution to postural control. *Rev Bras Fisioter, 14*(3), 267-275.

Voelcker-Rehage, C. (2008). Motor-skill learning in older adults—a review of studies on age-related differences. *European Review of Aging and Physical Activity, 5*(1), 5-16. doi: 10.1007/s11556-008-0030-9

Voelcker-Rehage, C., & Willimczik, K. (2006). Motor plasticity in a juggling task in older adults—a developmental study. *Age and Ageing, 35*(4), 422-427. doi: 10.1093/ageing/afl025