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RESEARCH PAPER

Effects of functional task exercise on everyday problem-solving ability and functional status in older adults with mild cognitive impairment—a randomised controlled trial

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Abstract

Objective: To investigate the effect of functional task exercise on everyday problem-solving ability and functional status in older adults with mild cognitive impairment compared to single exercise or cognitive training and no treatment control.
Design: A single-blind, four-arm randomised controlled trial.
Setting: Out-patient clinic and community centre.
Participants: Older adults with mild cognitive impairment aged ≥60 living in community.
Methods: Participants ($N = 145$) were randomised to 8-week functional task exercise ($N = 34$), cognitive training ($N = 38$), exercise training ($N = 37$), or wait-list control ($N = 36$) group. Outcomes measures: Neurobehavioral Cognitive Status Examination, Category Verbal Fluency Test, Trail Making Test, Problems in Everyday Living Test, Activities of Daily Living Questionnaire, Instrumental Activities of Daily Living Scale; Chair stand test, Berg Balance Scale, and Short Form-12 Health Survey were conducted at baseline, post-intervention and 5-months follow-up.
Results: Post-intervention results of ANCOVA revealed cognitive training improved everyday problem-solving ($P = 0.012$) and exercise training improved functional status ($P = 0.003$) compared to wait-list control. Functional task exercise group demonstrated highest improvement compared to cognitive training, exercise training and wait-list control groups in executive function (P range = 0.003–0.018); everyday problem-solving ($P < 0.001$); functional status (P range = <.001–0.002); and physical performance ($P = 0.008$) at post-intervention, with all remained significant at 5-month follow-up, and further significant improvement in mental well-being ($P = 0.043$).
Conclusions: Functional task exercise could be an effective intervention to improve everyday problem-solving ability and functional status in older adults with mild cognitive impairment. The findings support combining cognitive and exercise intervention may give additive and even synergistic effects.

Keywords: functional task exercise, everyday problem-solving, quality of life, combined training, mild cognitive impairment, older people

Key Points

- Dementia remains a priority health concern with escalating incidence.

- Even a mild increase in functional deficit is strongly predictive of progression to dementia in individuals with Mild cognitive impairment (MCI).
- Everyday problem-solving is closely related to visuospatial ability and both are important for independent functioning.
- Visuospatial abilities could be trained through practice of visuospatial tasks.
- Practice of visuospatial functional task exercise could be effective in promoting everyday problem-solving and functional status.

Background

Dementia remains a priority health concern burdening the public health system globally [1]. It is recognised as the most feared disease primarily due to its negative impact on independence in everyday function [1, 2]. The incidence of dementia is escalating with one new case every 3 s worldwide. In 2020, about 50 million people are living with dementia globally and the number will be tripled to over 150 million by 2050 [3]. Mild cognitive impairment (MCI), a state with increased dementia risk but may reverse to normal, has drawn increasing focus for identifying effective interventions to prevent or delay dementia onset [4]. Individuals with MCI are generally independent in daily functions but have difficulties in more complex instrumental activities of daily living (IADL) [5]. Studies have found that even a mild increase in IADL deficit is strongly predictive of progression to dementia in MCI [5, 6]. Functional independence including both physical and cognitive capacities is recognised as an important outcome by patients, caregivers and healthcare professions [7].

Everyday problem-solving ability is a higher order executive function, which is multidimentional and a strong predictor of everyday competence [8, 9]. Performance in everyday problem-solving could more adequately reflect an individual's functional abilities compared to outcomes on general cognitive functions [9].

Cognitive training (CT) based on use-it-or-lose-it and cognitive-enhancement theories may improve specific cognitive domains but have limited transfer to untrained domains or functional abilities [10, 11].

Exercise training (ET) may enhance neurogenesis and neuroplasticity, and also improve physical functioning, thus promoting cognitive and functional performance [11, 12].

However, benefits of exercise for individuals with cognitive impairment is still controversial [13]. Animal studies have shown combining exercise and enriched environment/cognitive stimulation could have additive effects on neurogenesis promoting long-term functional gains [14, 15]. Exercise could strongly induce neurogenesis while cognitive enrichment enhances the survival of newly generated neurons [15]. Combining cognitive and ETs might compensate for the underlying limitations of single training and better achieve potential additive training gains for individual with cognitive impairment [15, 16].

Successful performance of daily functional task involves complex integration of cognitive and physical abilities and can be cognitively challenging to individuals with MCI [17]. Functional task could possibly be used to exert cognitive and physical demands and act as a media of combined cognitive and exercise intervention to promote cognitive functions in individuals with MCI [18]. A structured functional task exercise (FTE) was developed using simulated visuospatial functional task as a means of combined cognitive and exercise intervention [18]. The exercise involves performing tasks following specific sequences and movement patterns at five levels of complexity. Core components include forward object placing and backward collection, unilateral/bimanual movement, task-switching, and a sit-stand movement to increase the physical and cognitive demand [18]. A brief description of the five exercise levels is illustrated in Appendix 1.

It is hypothesised that simulated functional task could be used as a combined cognitive and exercise intervention to exert cognitive and physical demands leading to cognitive benefits in older adults with MCI. This is a full-scale study of an initial pilot [19]. The aim of the present study was to investigate the effects of FTE on cognitive functions and functional status in older adults with MCI. Specifically, we compare the effects of FTE as a combined cognitive and exercise intervention to single exercise or cognitive intervention. We sought to determine whether combining cognitive and exercise intervention components could lead to additive effects relative to single exercise or cognitive intervention.

Methods

Study design

A four-arm, rater-blind, randomised controlled trial with participants randomly assigned to either a FTE group, a CT group, an ET group, or a wait-list control (WC) group according to a computer-generated sequence. All outcome assessments were conducted at baseline, post-intervention and 5-month follow-up from the start of intervention by independent assessors blind to group allocation. Ethics approval for this study was obtained from the Hospital Authority Research Ethics Committee. Written informed consents were obtained from all participants.

Participants

The study was conducted from March 2017 to May 2019 at two local out-patient clinics and a community center in Hong Kong. Older adults (age 60+) were eligible for the study if they met the inclusion criteria for MCI [20]:

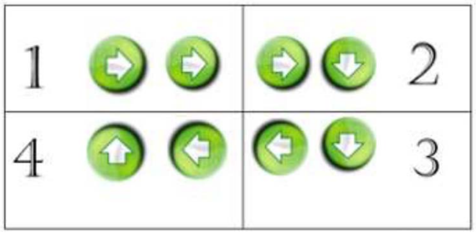

Figure 1. Basic movement pattern of forward placing.

(i) subjective memory/cognitive complaint; (ii) objective cognitive impairment in 1 or more domains; (iii) intact basic self-care functions; (iv) no confirmed dementia. The exclusion criteria were: (i) history of brain lesion/psychoactive substance abuse/co-morbid conditions associated with cognitive/functional decline; (ii) clinically significant depression; (iii) known psychiatric cause of cognitive dysfunction; (iv) medical conditions which rendered patients unable to participate physical activity; (v) taking medications with significant impacts on cognitive function and (vi) significant impairment of vision, hearing or communication that might affect participation in assessments or programme.

Sample size

According to previous study [21], a *priori* power analysis using G*Power [22] indicated a sample size of 142 across four groups would be required to detect a medium to large effect size in everyday problem-solving outcome, at 0.05% (two-sided) significant level and 80% power with ANCOVA.

Interventions

FTE group

The group received 12 sessions (60-minutes, 4–6/group) FTE training for 8 weeks, facilitated by a trained occupational therapist [18]. All sessions started with a warm-up (5–10 minutes) followed by 30–40-minute core FTE, ended with a cool-down (5–10 minutes). Participants will perform 1–2 exercise tasks in 1–3 sets of five repetitions (depending on individual ability) with 1–2 minutes' rest between each set. Basic pattern in Figure 1. Target exercise intensity was set at perceived exertion of moderate intensity (3–4, modified Borg scale) [23]. Task repetitions and activity speed were adjusted according to the individual progression.

CT group

The CT group received an existing computer-based CT [24] of attention, memory, executive function and visual perceptual function (12 sessions, 60-minutes session, 4–6/group) supervised by an occupational therapist.

ET group

The ET group performed 12 sessions of exercise (60-minutes session, 4–6/group), facilitated by an occupational therapist and an assistant for 8 weeks. All exercise sessions started with a warm-up (5–10-minutes), followed by 30–40 minutes moderate intensity aerobic exercise, including structured whole-body movement exercise, bicycle and arm ergometry, at 3–4/10 perceived exertion, ended with a cool-down (5–10 minutes).

WC group

Participants in control group maintained their normal activities and exercise practice during the 8-weeks period.

Measurements

Primary outcomes included general cognitive functions using Neurobehavioral Cognitive Status Examination (NCSE) and normal domains (0–10) were scored [25]; executive function using Category Verbal Fluency Test-animal (VFT) and Trail Making Tests A and B (TMT-A, TMT-B) [26, 27]; everyday problem-solving ability using Problems in Everyday Living Test (PEDL) which includes 14 questions and the first verbatim response is scored [28]; functional status using Activities of Daily Living Questionnaire (ADLQ) and Lawton Instrumental Activities of Daily Living Scale (Lawton-IADL) [29, 30]. Secondary outcomes included health-related quality of life (HRQoL) using Short Form-12 Health Survey (SF-12), with a higher physical component summary score (SF-12 PCS) or mental component summary score (SF-12 MCS) indicating better physical or mental HRQoL [31]. Also, Chair Stand Test (CST) and Berg Balance Scale (BBS) were used to assess physical performance [32, 33].

Statistical analysis

All analyses were performed using SPSS 26 (SPSS, Inc., Chicago, IL, USA). Baseline characteristics were compared using chi-square test and analysis of variance (ANOVA) when appropriate. Paired samples t-tests were performed to evaluate the within-group effects from baseline to post-intervention and 5-month follow-up. Analysis of covariance (ANCOVA) was conducted to evaluate the between-group differences at post-intervention and 5-month follow-up, using baseline scores, age, education, ambulatory level and exercise pattern as covariates to control the confounding effects of baseline characteristics and differences. *Post hoc* Bonferroni corrections were performed for pairwise comparisons of measures when significant between-group differences were revealed. Cohen's d was calculated for outcomes with significant differences to estimate the between-group effect sizes. Data were analysed according to the intention-to-treat principle. Missing data were replaced by the last available data. The statistic significant level was set at $P < 0.05$ (two-tailed).

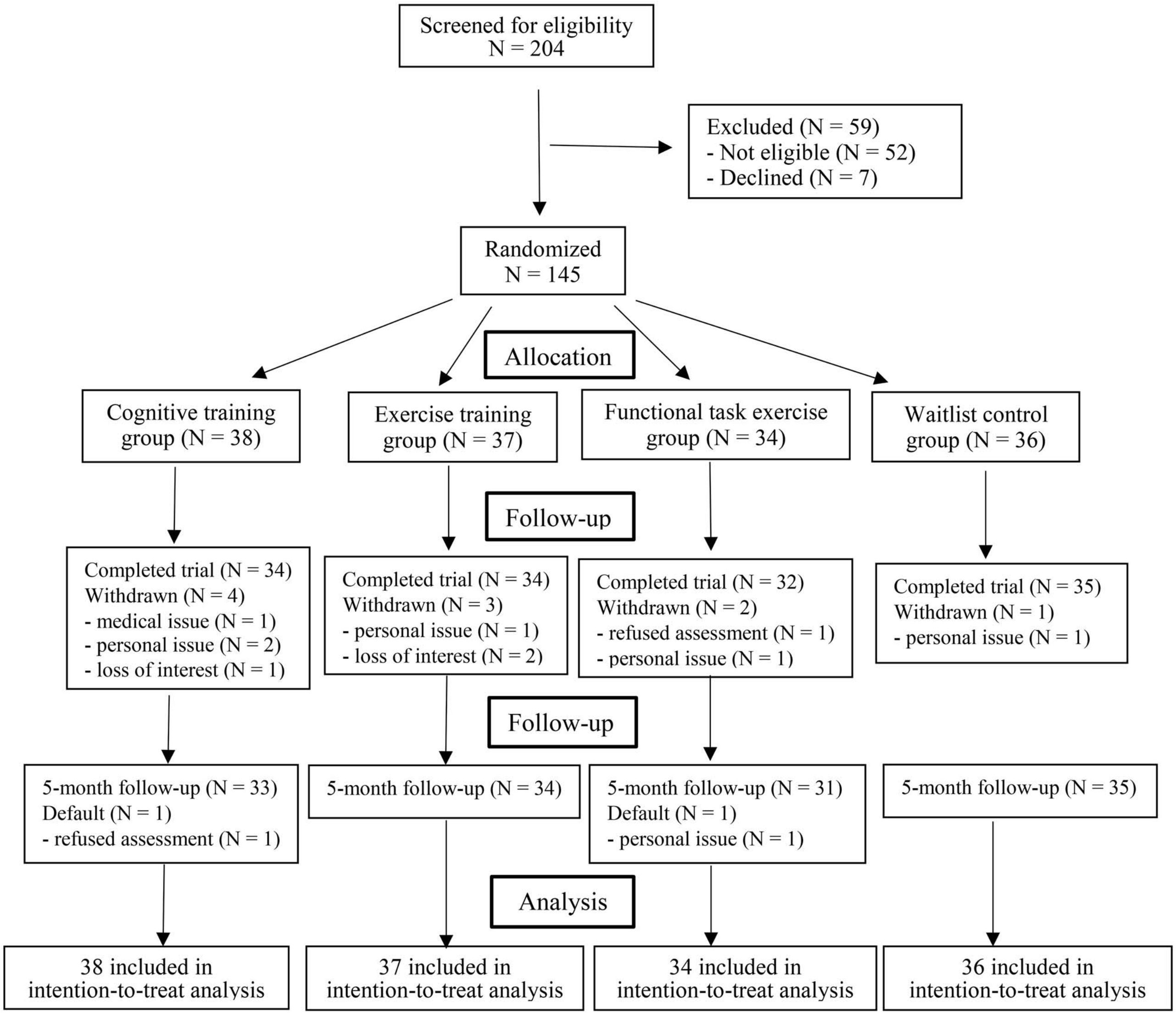

Figure 2. Study flow chart.

Results

Participant characteristics

A total of 204 potential participants were screened for eligibility. Figure 2 shows the flow of participants through the study. Of these, 145 participants (93 females; 52 males), aged 60–89 years (mean = 75.3, SD = 7.26), were assigned to the CT group ($N = 38$), ET group ($N = 37$), FTE group ($N = 34$), or WC group ($N = 36$). Baseline characteristics are tabulated in Table 1. No significant baseline differences were found in demographic characteristics or neuropsychological outcomes except the chair stand test score.

Compliance

Of the 145 participants completed the baseline assessments, 135 (93.1%) participants performed the post-intervention evaluation, and 133 (91.7%) participants completed the 5-month follow-up assessments. Dropout rates did not vary significantly between the groups at post-intervention (χ^2 (3) = 2.34, $P = 0.60$) and at 5-month follow-up (χ^2 (3) = 2.99, $P = 0.41$). No adverse events were reported from any of the groups.

Outcomes

Performance of the four groups for all outcome measures at baseline, post-intervention and 5-month follow-up as well as the between-group comparisons are illustrated in Tables 2 and 3. No significant differences were found in general cognitive function across the groups. Results of the paired samples t-tests showed the FTE group demonstrated significant within-group improvement in all other outcomes except physical HRQoL and an approaching significant improvement in executive function. The ET group also demonstrated significant improvement in functional status, physical performance and mental HRQoL whereas the CT group had significant improvement in executive function.

Table 1. Baseline characteristics of participants

Characteristics	Cognitive training group ($N=38$)	Exercise training group ($N=37$)	Functional task exercise group ($N=34$)	Wait-list control group ($N=36$)
Age, years, [range/mean (SD)]	62–88/76.32 (7.21)	64–89/77.35(6.66)	61–87/73.21(7.27)	60–89/74.14(7.53)
Gender, (female/male)	25(65.8)/13(34.2)	21(56.8)/16(43.2)	23(67.6)/11(32.4)	24(66.7)/12(33.3)
Education level, (illiterate/primary/secondary/tertiary)	8(21.1)/15(39.5)/13(34.2)/2(5.3)	9(24.3)/8(21.6)/13(35.1)/7(18.9)	9(26.5)/12(35.3)/8(23.5)/5(14.7)	9(25)/14(38.9)/9(25)/4(11.1)
Social status (living with family/alone)	27(71.1)/11(28.9)	32(86.5)/5(13.5)	29(85.3)/5(14.7)	31(86.1)/5(13.9)
Exercise per day (0/<30 min/>30 min)	6(15.7)/10(26.3)/22(57.9)	9(24.3)/8(21.6)/20(54.1)	5(14.7)/9(26.5)/20(58.8)	8(22.2)/12(33.3)/16(44.4)
Ambulatory level (unaided/with stick)	28(73.7)/10(26.3)	33(89.2)/4(10.8)	30(88.2)/4(11.8)	31(86.1)/5(13.9)
NCSE domain normal	6.55 ± 1.55	6.65 ± 1.20	7.20 ± 1.67	6.53± 1.61
TMT B/A	2.22± 0.91	2.21± 1.13	2.17 ± 1.27	2.03 ± 0.89
VFT	11.84 ± 4.18	10.89 ± 3.13	13.35 ± 4.63	11.67 ± 3.49
PEDL	16.78 ± 3.37	17.29 ± 3.19	16.52 ± 3.68	17.16 ± 3.27
ADLQ	10.28 ± 7.01	11.94 ± 8.33	7.94 ± 5.77	10.63 ± 8.43
Lawton IADL	18.76 ± 5.11	17.89 ± 4.33	20.44 ± 3.65	18.44 ± 4.16
SF-12 PCS	39.37 ± 11.13	37.69± 10.57	43.01 ± 8.68	37.58 ± 8.63
SF-12 MCS	48.97 ± 10.02	48.47 ± 9.24	47.07 ± 10.09	46.56 ± 9.73
CST	10.54 ± 4.18	7.81 ± 3.18	11.18 ± 4.84	9.34 ± 3.48
BBS	50.13 ± 6.18	48.51 ± 8.93	52.67 ± 5.01	49.77 ± 7.17

Note: Figures are mean ± SD or N (%); All participants are Chinese in Hong Kong. NCSE, Neurobehavioral Cognitive Status Examination; TMTB/A, Trail Making Test B to A ratio; VFT, Verbal Fluency Test; PEDL, Problems in Everyday Living Test; Lawton IADL, Lawton Instrumental Activities of Daily Living Scale; ADLQ, Activities of Daily Living Questionnaire; SF-12 PCS, Short Form-12 Health Survey physical component summary score; SF-12 MCS, Short Form-12 Health Survey Mental component summary score; CST, Chair Stand Test; BBS, Berg Balance Scale.

At post-intervention, results of the ANCOVA showed significant between-group differences among the four groups in executive function, everyday problem-solving, functional status and physical performance.

Pairwise comparison with *post hoc* Bonferroni correction further revealed the higher performance of the FTE group than all other groups.

CT group

The CT group did not show any significant between-group differences in any outcomes compared to the ET, FTE and WC groups.

ET group

The ET group showed higher performance in functional status compared to the WC group (ADLQ: $P=0.003$; $d=0.27$; Lawton-IADL: $P=0.033$; $d=0.25$).

FTE group

The FTE group demonstrated greatest improvements in executive function compared to the CT group (VFT: $P=0.003$; $d=0.67$) and WC group (VFT: $P=0.018$; $d=0.72$); everyday problem-solving compared to the CT group (PEDL: $P<0.001$; $d=1.10$), ET group (PEDL: $P<0.001$; $d=0.99$) and WC group (PEDL: $P<0.001$; $d=1.09$); functional status compared to WC group (ADLQ: $P=0.002$; $d=0.79$; Lawton-IADL: $P<0.001$; $d=0.99$); physical performance compared to WC group (CST: $P=0.008$; $d=0.95$) and approaching significance compared to CT group (BBS: $P=0.06$).

Sustainability of effects

At 5-month follow-up, significant between-group differences remained in executive function, everyday problem-solving, functional status and physical performance. In addition, significant difference was observed in mental HRQoL.

Pairwise comparison with *post hoc* Bonferroni correction revealed benefits of CT in improving everyday problem-solving ability. The FTE group also showed further improvement in mental HRQoL to significant level while all the improvement shown at post-intervention were sustained.

CT group

The CT group showed higher performance in everyday problem-solving compared to the WC group (PEDL: $P=0.012$; $P=0.32$).

ET group

The ET group only showed approaching significant between-group difference in functional status compared to the WC group (Lawton-IADL: $P=0.08$).

Table 2. Outcome comparisons at baseline and post-intervention

Measures	Cognitive training group ($N = 38$)			Exercise training group ($N = 37$)			Functional task exercise group ($N = 34$)			Wait-list control group ($N = 36$)		Post-test *P*-value (group)
	Baseline mean (SD)	Post-intervention mean (SD) (95% CI)	Adjusted mean difference (post-intervention) compared with control (95% CI)	Baseline mean (SD)	Post-intervention mean (SD) (95% CI)	Adjusted mean difference (post-intervention) compared with control (95% CI)	Baseline mean (SD)	Post-intervention mean (SD) (95% CI)	Adjusted mean difference (post-intervention) compared with control (95% CI)	Baseline mean (SD)	Post-intervention mean (SD) (95% CI)	
NCSE domain normal	6.55 (1.55)	6.45 (1.98) (−0.39–0.59)	0.21 (−0.59–1.00)	6.65 (1.20)	6.46 (1.93) (−0.26–0.85)	0.14 (−0.65–0.93)	7.20 (1.67)	6.97 (2.13) (0.21 −−0.19)	0.02 (−0.82–0.79)	6.53 (1.61)	6.36 (1.58) (−0.26–0.59)	0.850
***P*-value**[#]		0.668			0.400			0.274			0.439	
TMT – B/A	2.22 (0.91)	2.21 (0.90) (−0.35–0.35)	0.19 (−0.31–0.69)	2.21 (1,13)	2.21 (1.12) (−0.10–0.65)	0.12 (−0.62–0.37)	2.17 (1.27)	1.94 (0.75) (−0.14–0.59)	0.07 (−0.57–0.43)	2.03 (0.89)	1.98 (0.76) (−0.31–0.41)	0.35
***P*-value**[#]		0.99			0.148			0.22			0.769	
VFT	11.84 (4.18)	11.53 (3.09) (−0.63–1.26)	0.08 (−1.53–1.69)	10.89 (3.13)	11.22 (3.01) (−1.25–0.60)	0.73 (−0.86–2.32)	13.35 (4.63)	14.15 (4.62) (−1.69–0.10)	1.83 (0.21–3.46)	11.67 (3.49)	11.11 (3.76) (−0.39–1.50)	**0.011**[*]
***P*-value**[#]		0.504			0.482			0.080			0.241	
PEDL	16.78 (3.37)	16.26 (3.97) (−0.59–1.64)	0.13 (−1.77–1.51)	17.29 (3.19)	16.94 (3.37) (−0.44–1.14)	0.12 (−1.75–1.50)	16.52 (3.68)	20.15 (3.06) (−4.70–−2.53)	3.58 (1.93–5.23)	17.16 (3.27)	16.92 (2.86) (−0.54–1.04)	**0.000**[**]
***P*-value**[#]		0.348			0.376			**0.000**[**]			0.529	
ADLQ	10.28 (7.01)	11.00 (7.08) (−2.28–0.86)	2.04 (−4.71–0.64)	11.94 (8.33)	10.70 (7.89) (−0.29–2.77)	3.53 (−6.17 –−0.88)	7.94 (5.77)	6.82 (6.58) (−0.25–2.48)	3.73 (−6.42 to −1.04)	10.63 (8.43)	12.92 (8.66) (−3.60—−0.95)	**0.001**[**]
***P*-value**[#]		0.365			0.109			0.107			**0.001**[**]	
Lawton IADL	18.76 (5.11)	18.76 (5.29) (−0.93 to 0.93)	1.32 (−0.24–2.87)	17.89 (4.33)	18.68 (3.58) (−1.55 to −0.02)	1.63 (0.09– 3.17)	20.44 (3.65)	21.85 (3.85) (−2.25 to −0.57)	2.56 (0.99–4.13)	18.44 (4.16)	17.64 (4.73) (−3.60 to −0.95)	**0.000**[**]
***P*-value**[#]		1.00			**0.044**[*]			**0.002**[**]			0.078	
SF-12 PCS	39.37 (11.13)	39.74 (11.13) (−3.27 to 2.54)	1.82 (−3.59 to 7.23)	37.69 (10.57)	39.67 (9.71) (−5.16 to 1.18)	2.33 (−2.93 to 7.60)	43.01 (8.68)	42.62 (8.79) (−2.34 to 3.13)	1.41 (−4.01 to 6.83)	37.58 (8.63)	37.91 (10.79) (−3.41 to 2.73)	0.868
***P*-value**[#]		0.801			0.212			0.772			0.824	
SF-12 MCS	48.97 (10.02)	50.14 (9.84) (−4.11 to 4.17)	1.40 (−3.84 to 6.65)	48.47 (9.24)	52.36 (7.89) (−7.41 to −0.39)	3.84 (−1.25 to 8.94)	47.07 (10.09)	50.32 (8.76) (−5.87 to −0.63)	2.89 (−2.24 to 8.03)	46.56 (9.73)	47.16 (11.44) (−3.49 to 2.30)	0.381
***P*-value**[#]		0.424			**0.030**[*]			**0.017**[*]			0.678	
CST	10.54 (4.18)	10.83 (4.50) (−1.22 to 0.64)	0.76 (−1.02 to 2.55)	7.81 (3.18)	9.35 (3.81) (−2.03 to −0.55)	1.55 (−0.25 to 3.36)	11.18 (4.84)	13.41 (5.56) (−3.20 to −0.55)	2.21 (0.41–0.40)	9.34 (3.48)	9.11 (3.18) (−0.52 to 0.98)	**0.007**[**]
***P*-value**[#]		0.537			**0.001**[*]			**0.007**[**]			0.542	
BBS	50.13 (6.18)	49.32 (8.59) (−0.82 to 2.45)	1.53 (−4.10 to 1.05)	48.51 (8.93)	47.92 (1.13) (−0.87 to 2.05)	1.06 (−3.58 to 1.47)	52.67 (5.01)	53.65 (4.49) (0.01 to −1.99)	0.39 (−2.20 to 2.97)	49.77 (7.17)	50.19 (7.10) (−1.57 to −0.74)	0.170
***P*-value**[#]		0.319			0.415	0.361		0.054			0.469	

Note: CI, confidence interval. NCSE, Neurobehavioral Cognitive Status Examination; TMTB/A, Trail Making Test B to A ratio;VFT, Verbal Fluency Test; PEDL, Problems in Everyday Living Test; ADLQ, Activities of Daily Living Questionnaire (higher scores indicate lower performance); Lawton IADL, Lawton Instrumental Activities of Daily Living Scale; SF-12 PCS, Short Form-12 Health Survey physical component summary score; SF-12 MCS, Short Form-12 Health Survey Mental component summary score; CST, Chair Stand Test; BBS, Berg Balance Scale. *P*-value[#] = within-group effects (by time); [*] $P < 0.05$; [**] $P < 0.01$. *P*-value (group) = between-group effects; [*] $P < 0.05$; [**] $P < 0.01$.

Table 3. Outcome comparisons at baseline and 5-month follow-up

Measures	Cognitive training group ($N = 38$)			Exercise training group ($N = 37$)			Functional task exercise group ($N = 34$)			Wait-list control group ($N = 36$)		Post 5-month *P*-value (group)
	Baseline mean (SD)	Post 5-month follow-up mean (SD) (95% CI)	Adjusted mean difference (post 5-month) compared with control (95% CI)	Baseline mean (SD)	Post 5-month follow-up mean (SD) (95% CI)	Adjusted mean difference (post 5-month) compared with control (95% CI)	Baseline mean (SD)	Post 5-month follow-up mean (SD) (95% CI)	Adjusted mean difference (post 5-month) compared with control (95% CI)	Baseline mean (SD)	Post 5-month follow-up mean (SD) (95% CI)	
NCSE domain normal	6.55 (1.55)	6.81 (1.81) (−0.67 to 0.15)	0.40 (−0.44 to 1.25)	6.65 (1.20)	6.73 (1.89) (0.22 to −0.54)	0.27 (−0.57 to 1.11)	7.20 (1.67)	7.23 (2.14) (−0.48 to 0.42)	0.17 (−0.69 to 1.02)	6.53 (1.61)	6.53 (0.26) (−0.53 to 0.53)	0.625
***P*-value**$^{\#}$		0.201			0.723			0.897			1.000	
TMT – B/A	2.22 (0.91)	2.33 (1.08) (−0.43 to 0.21)	0.23 (−0.62–0.15)	2.21 (1,13)	2.39 (0.99) (−0.62 to 0.26)	0.36 (−0.17–0.88)	2.17 (1.27)	1.86 (0.71) (−0.07 to 0.69)	0.14 (−0.66–0.38)	2.03 (0.89)	1.94 (0.55) (−0.21 to 0.38)	**0.036***
***P*-value**$^{\#}$		0.468			0.421			0.114			0.552	
VFT	11.84 (4.18)	13.18 (3.54) (−2.06 to −0.62)	1.75 (−0.48 to 3.99)	10.89 (3.13)	11.81 (4.22) (0.13–2.95)	1.22 (−1.01 to 3.45)	13.35 (4.63)	15.11 (5.68) (−3.60 to 0.07)	2.66 (0.40–4.92)	11.67 (3.49)	11.13 (4.28) (−0.39 to 1.45)	**0.018***
***P*-value**$^{\#}$		**0.001****			0.109			0.060			0.256	
PEDL	16.78 (3.37)	17.13 (3.55) (−1.35 to 0.67)	1.5 (0.35–2.65)	17.29 (3.19)	16.21 (3.11) (0.19–1.96)	0.10 (−1.66 to 1.46)	16.52 (3.68)	20.14 (3.19) (−4.73 to −2.50)	4.26 (2.69–5.84)	17.16 (3.27)	16.30 (8.43) (0.15–1.56)	**0.000****
***P*-value**$^{\#}$		0.498			**0.018***			**0.000****			**0.018***	
ADLQ	10.28 (7.01)	10.81 (7.46) (−1.99 to 0.94)	1.95 (−5.39–1.49)	11.94 (8.33)	12.89 (9.75) (−3.36 to 1.47)	1.07 (−4.49 to 2.35)	7.94 (5.77)	6.61 (6.83) (−0.03 to 2.68)	3.51 (−6.96 to −0.06)	10.63 (8.43)	12.41 (9.19) (−3.57 to 0.02)	0.054
***P*-value**$^{\#}$		0.471			0.433	0.433		0.057			0.052	
Lawton IADL	18.76 (5.11)	18.26 (5.31) (−.54– 1.54)	1.02 (−0.68 to 2.72)	17.89 (4.33)	17.89 (4.51) (−1.08 to 1.08)	1.06 (−3.38–0.13)	20.44 (3.65)	21.88 (3.54) (−2.34 to −0.54)	2.68 (0.97–4.40)	18.44 (4.16)	17.61 (4.36) (−3.57 to 0.02)	**0.001****
***P*-value**$^{\#}$		0.334			1.00			**0.003****			**0.038***	
SF-12 PCS	39.37 (11.13)	39.37 (11.33) (−2.53 to 2.54)	1.89 (−3.58 to 7.35)	37.69 (10.57)	39.32 (9.75) (−5.77 to 2.50)	1.99 (−3.40 to 7.37)	43.01 (8.68)	41.67 (9.35) (−1.71 to 4.39)	1.07 (−4.44 to 6.57)	37.58 (8.63)	37.76 (8.63) (−3.03 to 2.66)	0.915
***P*-value**$^{\#}$		0.997			0.428			0.378			0.894	
SF-12 MCS	48.97 (10.02)	47.58 (12.73) (−3.05 to 5.84)	1.88 (−2.55–6.31)	48.47 (9.24)	50.39 (9.30) (−5.02 to 1.17)	0.45 (−3.22–4.13)	47.07 (10.09)	53.00 (7.30) (−9.11 to −2.75)	3.49 (−6.86 to −0.11)	46.56 (9.73)	49.75 (8.75) (−2.22 to −0.27)	**0.024***
***P*-value**$^{\#}$		0.528			0.216			**0.001****			**0.033***	
CST	10.54 (4.18)	11.52 (4.64) (−1.61 to 0.26)	0.79 (−1.33 to 2.91)	7.81 (3.18)	10.10 (3.55) (−2.51 to −1.02)	1.64 (−0.57 to 3.85)	11.18 (4.84)	14.56 (5.59) (−4.21 to −1.84)	2.92 (0.81−5.04)	9.34 (3.48)	9.82 (3.66) (−1.61 to 1.19)	**0.002****
***P*-value**$^{\#}$		0.149			**0.000****			**0.000****			0.768	
BBS	50.13 (6.18)	50.18 (9.47) (−2.31 to 2.21)	0.44 (−3.65 to 2.76)	48.51 (8.93)	47.86 (10.71) (−20.77 to 2.07)	1.50 (−4.82 to 1.81)	52.67 (5.01)	53.5 (3.67) (−1.60 to −0.43)	0.64 (−2.58 to 3.86)	49.77 (7.17)	50.34 (1.19) (−2.21 to 1.81)	0.649
***P*-value**$^{\#}$		0.963			0.361			**0.039***			0.841	

Note: CI, confidence interval. NCSE, Neurobehavioral Cognitive Status Examination; TMTB/A, Trail Making Test B to A ratio;VFT, Verbal Fluency Test; PEDL, Problems in Everyday Living Test; ADLQ, Activities of Daily Living Questionnaire (higher scores indicate lower performance); Lawton IADL, Lawton Instrumental Activities of Daily Living Scale; SF-12 PCS, Short Form-12 Health Survey physical component summary score; SF-12 MCS, Short Form-12 Health Survey Mental component summary score; CST, Chair Stand Test; BBS, Berg Balance Scale. *P*-value$^{\#}$ = within-group effects (by time); $^{*}P < 0.05$; $^{**}P < 0.01$. *P*-value (group) = between-group effects; $^{*}P < 0.05$; $^{**}P < 0.01$.

FTE group

The FTE group still showed higher improvement in executive function compared to the ET group (TMT B/A: $P = 0.019$; $d = 0.26$) and WC group (VFT: $P = 0.012$; $d = 0.79$); everyday problem-solving compared to CT group (PEDL: $P < 0.001$; $d = 0.89$), ET group (PEDL: $P < 0.001$; $d = 1.25$) and WC group (PEDL: $P < 0.001$; $d = 0.60$); functional status compared to the WC group (ADLQ: $P = 0.044$; $d = 0.72$; Lawton-IADL: $P < 0.001$; $d = 1.01$); physical performance compared to the CT group (CST: $P = 0.05$; $d = 0.59$) and WC group (CST: $P = 0.002$; $d = 1.00$).

Moreover, the FTE group also showed greater improvement in mental HRQoL compared to the CT group (SF-12 MCS: $P = 0.029$; $d = 0.41$) and WC group (SF-12 MCS: $P = 0.043$; $d = 0.40$).

Discussion

The present study was to investigate whether FTE could improve the everyday problem-solving ability and functional status of older adults with MCI compared to single exercise or CT and no treatment control. Only the FTE group demonstrated higher performance than both the WC group and the comparison groups in all outcomes showing significant between-group differences. The ET group and the CT group only showed higher performance in functional status and everyday problem-solving respectively compared to the WC group.

The FTE group showed the greatest improvement in executive function compared to the CT group and WC group with moderate effect size; everyday problem-solving compare to all the CT, ET and WC groups with large effect size; functional status compared to the WC group with large effect size; and physical performance compared to the WC group with large effect size at post-intervention. The improvement of the FTE group was also sustained in all outcomes with moderate to very large effect sizes at 5-month follow-up.

Importantly, the FTE group also showed greater improvement in mental well-being compared to the CT group and WC group. Studies on quality of life (QoL) found older adults with MCI reported reduced satisfaction with daily life and having lower overall mental well-being compared to both those with normal cognitive and dementia [34, 35]. Limitation in IADL and frustration due to reduced functional independence are the key contributors to reduction in health and mental well-being and related QoL in individuals with MCI [35, 36].

Everyday problem-solving, which is referred as the cognitive dimension of everyday functional abilities, could be benefited by CT [37] whereas the physical contribution, such as muscle strength, of functional abilities could be enhanced by practicing exercise [12]. These prior findings are in alignment with the results of our present study that CT could benefit everyday problem-solving ability and physical exercise could benefit functional status.

Notably, the FTE group demonstrated the combination of both cognitive and exercise effects and showed additive benefits on improving both everyday problem-solving and functional status. The FTE group showed the highest performance in improving various cognitive, functional and physical outcomes compared to single cognitive or ET and WC groups whereas the improvement could be sustained. Decline in cognitive, physical and functional outcomes are important indicators of disease progression in people with cognitive impairment [38]. Performance of the FTE could possibly contribute to delay the onset or progression of dementia.

The present promising findings support previous studies which reported greater beneficial effects of combining cognitive and ETs as compared to single component training alone [14, 15]. The functional tasks used in this study are visuospatial task which involves placing and collecting objects following specific sequences and patterns. Although this is seemingly a simple task, even cognitively healthy older adults may frequently complain about difficulties in locating everyday objects [39]. Indeed, successful functional interactions in the visual world involves complex visuospatial functions and manipulation of visuospatial information which allow us to orient our attention to relevant stimuli among numerous details in surrounding environment, and thus enable us to interpret the visuospatial world around and understand the dynamics between ourselves and the environment to facilitate achievement of our goal-orientated tasks in everyday life, such as judging and locating familiar landmarks for finding the way to destination safely [40]. Such visuospatial thinking actually inherently links to everyday problem-solving, where reasoning and complex cognitive operations are employed to identify viable solutions in response to problems facing in daily life [41, 42] Visuospatial abilities are crucial for independent functioning and is predictive to daily function [40, 43]. However, individuals with MCI show impairment in visuospatial functions [44, 45]. Recent review and studies found visuospatial abilities could be trained through practice of visuospatial tasks and with the training gains transferable to untrained tasks [46, 47]. The generalisation of training gains could be associated with enhanced attentional resources and strengthening of attentional neural networks essential for various cognitive outcomes [48]. Neuroimaging studies also have found that visuospatial training could increase neurogenesis of hippocampus [49] and activate dorsolateral prefrontal cortex [50], which are important brain areas for executive functions, working memory and selective attention [51]. The practice of the visuospatial tasks in FTE could possibly enhance visuospatial abilities and thus everyday problem-solving, as well as increase attentional resources which further enhances various cognitive and functional outcomes. Studies have proposed the survival and integration of the exercise-primed new neurons into the functional network of the brain is activity-dependent which enriched environment plays a significant role [14, 15]. Therefore, while combining cognitive and exercise intervention could lead to additive and even synergistic effects as revealed in the present study, the inclusion of visuospatial components as the cognitive challenges/enrichment could be crucial, in particular when functional independence is an important and desirable outcome for any interventions. Yet, in order to reach a survival-promoting effect, the cognitive demand has to be gauged and maintained at a sufficient challenging but manageable level through manipulation of task complexity such that the novelty and thus the enriched component can be ensured [15], which was also achieved in the FTE programme by including five levels of tasks.

Limitations

Although the results of this study are encouraging, there are limitations that warrant mention. First, the populations included were Chinese older adults in Hong Kong and this may limit the generalisation of the findings in other populations. Further studies in different countries are needed to validate the efficacy of using FTE as an intervention. Second, the small sample size did not allow stratification of participants into sub-groups such as different age and exercise pattern which may influence intervention responses. Another limitation was the inclusion of the CST as one of the physical outcomes, which was similar to one of the exercise components in FTE and might contribute to performance bias. Although the BBS was also included, a ceiling effect was reported in older adult [52]. Further, resources limitation did not allow evaluation of sustainability of intervention effects over a longer period, therefore, further studies with longer follow-up after intervention cessation are still needed.

Conclusion

In conclusion, FTE using simulated functional task as combined cognitive and exercise intervention is effective for improving everyday problem-solving ability, functional status and mental well-being in older adults with MCI. This study provides evidence that combining cognitive and exercise interventions could lead to additive and even synergistic effects compared to either intervention alone. Meanwhile, including visuospatial component and maintaining novelty to allow continuing manageable cognitive challenge can be crucial.

Supplementary Data: Supplementary data mentioned in the text are available to subscribers in *Age and Ageing* online.

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