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Dual-task interference is related to attentional level in healthy farmers
An observational study

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Abstract

Dual-task interference (DTI) is a decreased performance when conducting 2 tasks simultaneously, such as cognitive and motor tasks. This study aimed to identify the DTI-related factors with individually computerized interference and analyze the relative implications of decreasing DTI in healthy farmers.

It followed 3 computerized experiments:

(1) cognitive task (CT): release button 1 (BT1) as rapidly as possible when the word and color matched,

(2) motor task (MT): release BT1 and then tap button 2 (BT2) 10 times as rapidly as possible when "O" was presented, and

(3) dual tasks (DT): combination of CT and MT elements.

The reaction time of correct releases (CRT) of BT1 in all tasks was measured, and the CRT ratios of DT were divided by the CRT values from CT and MT to obtain the DTI value. CRT during CT and MT was decreased compared to that during DT. The interference by CT (CRT of DT/CRT of MT × 100, CTI) was increased compared to the interference by MT (CRT of DT/CRT of CT × 100, MTI). Additionally, comprehensive baseline characteristics, body composition, psycho-cognitive, and physical factors were assessed.

Of a total of 54 participants, 16 are males (67.2 ± 8.9 years) and 38 females (62.5 ± 6.6 years). CTI showed significant correlations with age ($r = 0.436$, $P < .001$), farming period ($r = 0.290$, $P = .033$), score of the Mini-Mental State Examination in the Korean version of CERAD Assessment Packet ($r = -0.329$, $P = .015$), CRT of the Go/No-Go test ($r = 0.67$, $P < .001$), score of the short physical performance battery ($r = -0.304$, $P = .026$), and time of the timed up and go test ($r = 0.364$, $P = .007$). Regression analysis showed that the CRT of the Go/No-Go test ($\beta = 0.558$, $P < .001$) was the most explanatory factors for CTI.

Based on the individualized DTI values quantified, interference during cognitive task was mostly related to CRT of Go/No-Go test, reflecting the attentional level. These results could suggest strategies for the active attentional training to reduce DTI and passive simplification and modification of lifestyles.

Abbreviations: 6MWT = six-minute walk test, BIA = bio-electrical impedance analysis, CT = cognitive task, CTI = interference by cognitive task in DTI, DT = dual tasks, DTI = dual-task interference, FSS = Fatigue Severity Scale, K-BDI = Korean version of Beck Depression Inventory, MMSE-KC = Mini-Mental State Examination in the Korean version of CERAD Assessment Packet, MT = motor task, MTI = interference by motor task in DTI, PPT = pain pressure threshold, SF36 = 36-Item Short-Form Health Survey, SPPB = short physical performance battery, TUG = Timed Up & Go test, VAS = Visual Analog Scale.

Keywords: attention, cognition, dual task, exercise, interference, training

1. Introduction

In terms of daily living, which might be important in aging society in terms of independency,[1] virtually all tasks of daily life consist of 2 or more motor or/and cognitive performances, called the dual-task paradigm (DT). DT also includes interference, interruption by another task during the dual-task, called dual-

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task interference (DTI). The theory of DTI has been supported by limited information processing capacity at certain times (serial bottleneck model),[2] and a shared capacity for the given task (capacity sharing model).[3]

DTI is observed in all age groups and is reported to be increasing, especially in the elderly[4] and those with neurological disorders.[5] Several studies have reported age-related DTI changes in gait velocity, standing, and turn speed, as well as increased postural and velocity sway in balance tasks, compared with younger adults.[6,7] The increased DTI in stroke patients with cognitive dysfunction or gait disturbance occurs due to reduced ability of simultaneously dealing with cognitive and motor function.[8] DTI studies of stroke patients found a decrease in the gait velocity, stride length,[9] and balance[10] during the dual task, compared with healthy subjects. These studies have shown the close association between DTI, aging, and neurological disorders.

For the life independency in older people, the systematic reduction of DTI should be coordinated with daily activities composed of various physical/cognitive tasks and lifestyle modifications. Moreover, active training to reduce DTI is needed for aging societies.

Thus, the presence of DTI and an individualized understanding and analysis of the correlation between cognitive or motor tasks on DTI will help researchers to develop the DT paradigms to analyze the performance of daily activities. However, there has been no study that has examined an individual's background and characteristics in relation to DTI.

Based on the hypothesis that cognitive-motor interference may be affected by individual characteristics and lead to DTI caused by different factors, proving the causes of DTI may be useful for composing a training protocol based on modifying life style/ activities to address DTI in an individualized manner. This study was purposed to identify the DTI related factors with individually computerized interference to analyze the relative implications among the comprehensive baseline characteristics, body composition, psycho-cognitive, and physical factors of decreasing DTI in healthy subjects.

2. Methods

2.1. Participants

This study is a cross-sectional analysis of baseline data of a randomized case control study in Korean healthy farmers (Healthy and Long life Program in Farm; HELPinFarm, CRIS number KCT0002366, http://cris.nih.go.kr).[11] Participants were randomly enrolled in the Gangwon Province of South Korea (November 2017 to December 2018) and written informed consents were obtained from the participation in this study.

Initially, a total of 75 people were enrolled. The inclusion criteria were as follows: 50 to 85 years of age and a healthy farmer with no cognitive and physical disorders. Twenty-one people were excluded from the study on the following exclusion criteria; a history of stroke (n=4), dementia (n=8), left-handedness (n=2), and poor performance in the experimental tasks (n=7) (Fig. 1). Finally, a total of 54 participants (16 males and 38 females) were included in the analysis. Sample size for 1 proportion cross-sectional analysis was calculated as 54, with $\alpha = 0.05$, population proportion of 0.01, and effect size of 3.5 (5% absolute precision with 95% level of significance).

This study was approved by the Institutional Review Board of the Kangwon National University Hospital (IRB No. 2017–04–017– 006, Approved from May 23, 2017) and a trial registration number was obtained from the Clinical Research Information Service (HELPinFarm, KCT0002366, registered on June 30, 2017).

2.2. Computerized single/dual tests measurement.

DTI was assessed using computerized measurement. Participants were asked to perform randomly presented DTI experimental tasks after sufficient explanation and practice of tests (a cognitive, a motor, and a dual task) using computer programs (Superlab pro v.4.0 software, Cedrus Corporation, San Pedro, CA). Figure 2 shows the DTI experimental tasks in this study.

The Go/No-Go signs are randomly displayed 48/48 times on the computer screen. All tasks started when the participants pressed button 1 (BT1).

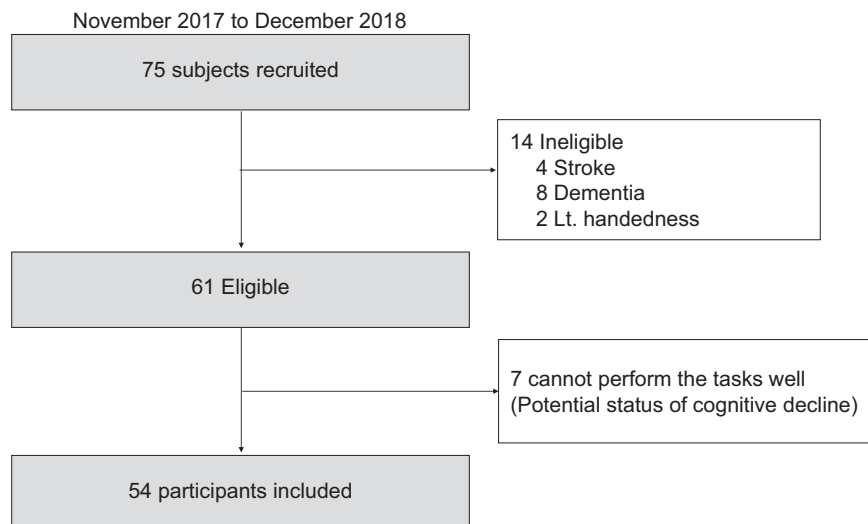**Figure 1.** Inclusion flow chart.

November 2017 to December 2018

75 subjects recruited

14 Ineligible
  4 Stroke
  8 Dementia
  2 Lt. handedness

61 Eligible

7 cannot perform the tasks well
(Potential status of cognitive decline)
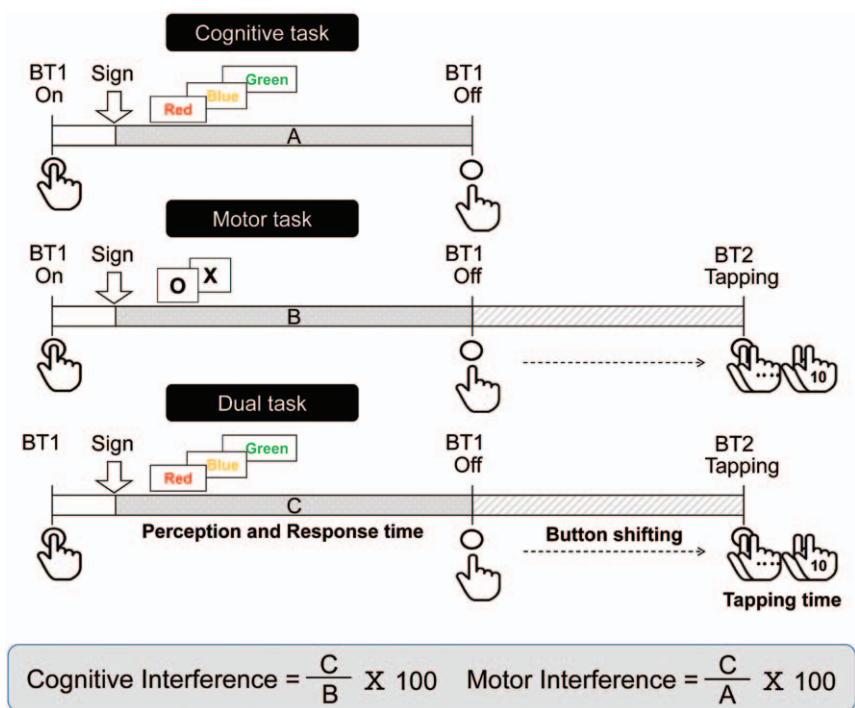
54 participants included

Figure 2. Experimental designs of cognitive, motor, and dual task. The perception and response times (A, B, C) of each task were used to quantify the interference.

In the cognitive task, the Go action is the motion of releasing BT1. the Color-Word Interference Test (Stroop test)[12] was used for the cognitive task; when the word and its ink color on the screen matched, it means a Go sign and the participants were asked to perform releasing BT1, but when they did not match, it means a No-Go sign and the participants were asked to make no response by continuing to press BT1. In the motor task, "O" was the Go sign and "X" was the No-Go sign; the Go motion was to release BT1 and then press button 2 (BT2) 10 times, as quickly as possible. In the dual task, the cognitive and motor tasks were combined.

2.3. Calculation method to indicate individualized DTI

The reaction times (RT) of correct releases (CRT) of BT1 in all tasks were measured, and the CRT ratios in the DT were divided by the CRT of the CT and MT to obtain the DTI values. A previous study had identified the DTI of the experimental design, shown significant differences in CRT (MT < CT < DT), and had identified residual cognitive loading to be the CRT of CT and preceding cognitive loading to be the CRT of MT. Moreover, the CRT for each task was significantly different (MT < CT < DT, F = 17.071, $P < .001$) in this study.

The following formulas were calculated and used to analyze the related factors for each cognitive loading that constitutes the DTI.

Interference by Cognitive Task in DTI(CTI)
= [DT response time/ MT response time] × 100

Interference by Motor Task in DTI(MTI)
= [DT response time/ CT response time] × 100

MTI and CTI were used to analyze relationship between the various factors and each CT or MT interference to DTI.

2.4. Outcome measurements

The participants' sex (male/female), age (year), education period (year), farming period (year), farm working time per year (hour), housekeeping time per year (hour), exercise time per year (hour), and total working time per year (hour) were assessed as baseline characteristics.

For body composition was measured using the Bio-electrical Impedance Analysis (BIA) method, and a body water analyzer (InBody S10, InBody Corp., Seoul, South Korea) was used to determine the skeletal muscle mass (kg), body fat mass (kg), total body water (L), and body mass index (kg/m^2).

Psycho-cognitive factors were measured using a Mini-Mental State Examination in the Korean version of CERAD Assessment Packet (MMSE-KC),[13] Go/No-Go test,[14] Visual Analog Scale of Stress (VAS, 0 to 10), fatigue severity scale (FSS),[15] and the Korean Version of the Beck Depression Inventory (K-BDI).[16] The painful pressure threshold (PPT) was measured using a digital pressure algometer (Commander Algometer, JTECH Medical, Salt Lake City, UT, USA),[17] and health-related qualities of life were assessed by calculating the means of the Medical Outcomes Study 36-Item Short-Form Health Survey (SF-36).[18,19]

Physical performance factors were determined by grip strength using the KS301 Lavisen electronic handgrip dynamometer (Lavisen Co. Ltd., Namyangju, Korea), repetitive finger tapping,[20] the short physical performance battery (SPPB) protocol,[21] timed up and go test (TUG),[22] and the six-minute walk test.[23]

2.5. Statistical analysis

Comparisons of baseline data between male and female farmers were analyzed using the independent samples t-test. Pearson's correlation analyses were used to show the associations between

individual baseline data, and CTI/MTI. To identify the most explanatory factor for DTI, a stepwise, multiple linear regression analysis was performed. P values < .05 were considered statistically significant. All data were analyzed using the Statistical Package for the Social Sciences, version 20.0 (SPSS, Chicago, IL).

3. Results

3.1. Baseline data of participants

Fifty-four healthy farmers (16 males and 38 females) were included in the analysis. Table 1 shows the baseline characteristics, body composition, psycho-cognitive, physical performance factors, including gender, and the results of the computerized single/dual measurements. In the comparisons between gender (male vs female), the age (67.2 ± 8.9 vs 62.5 ± 6.6, $P = .036$), education period (11.3 ± 4.0 vs 7.3 ± 3.2, $P < .001$), skeletal muscle mass (31.7 ± 5.8 vs 23.6 ± 3.1, $P < .001$), total body water

(41.5 ± 6.9 vs 31.7 ± 3.9, $P < .001$), painful pressure threshold (46.0 ± 6.5 vs 39.4 ± 9.9, $P = .006$), and grip strength (35.5 ± 9.9 vs 21.8 ± 4.6, $P < .001$) were all significantly higher in males than in females. However, housekeeping time per year (101.3 ± 146.5 vs 810.0 ± 561.1, $P < .001$) and body fat mass (12.0 ± 4.0 vs 17.0 ± 5.0, $P < .001$) were significantly higher in females than in males. The remaining variables were not significantly different between groups. Ultimately, the study determined that gender was not an influencing factor because there was no significant difference due to gender among the DTI variables (MTI and CTI).

3.2. Correlation between DTI and individual baseline characteristics

Table 2 reports the Pearson correlation coefficients between the CTI and MTI, and the various characteristics, and shows that there was no statistically significant association between MTI and baseline data. However, CTI was significantly correlated with age

Table 1

The results of baseline data in participants.

Variable	Total (n=54) Mean±SD	Male (n=16) Mean±SD	Female (n=38) Mean±SD	P value
Baseline characteristics				
Age (y)	63.9±7.6	67.2±8.9	62.5±6.6	.036[*]
Education period (y)	8.4±3.9	11.3±4.0	7.3±3.2	<.001[**]
Farming period (y)	29±15.7	31.1±20.0	28.1±13.6	.523
Farm working time per year (h)	3041.7±1399.2	3060.0±1339.8	3033.9±1441.0	.951
Housekeeping time per year (h)	600±576.7	101.3±146.5	810.0±561.1	<.001[**]
Exercise time per year (h)	158.8±201.4	199.7±295.3	141.6±147.4	.338
Body composition				
SMM (kg)	26±5.5	31.7±5.8	23.6±3.1	<.001[**]
BFM (kg)	15.5±5.2	12.0±4.0	17.0±5.0	<.001[**]
TBW (ℓ)	34.6±6.6	41.5±6.9	31.7±3.9	<.001[**]
BMI (kg/m^2)	25.2±2.7	25.4±2.3	25.2±2.8	.728
Psycho-cognitive factors				
MMSE-KC (0–30)	27.6±2.0	27.3±2.2	27.7±1.8	.409
CRT of Go/No-Go test (ms)	499.4±153.6	510.6±190.3	494.7±138.0	.732
PPT (N)	41.4±9.5	46.0±6.5	39.4±9.9	.006[**]
Stress (0–10)	3.1±2.5	3.1±2.2	3.1±2.6	.979
FSS (1–7)	2.1±1.3	1.9±1.4	2.2±1.3	.357
K-BDI (0–63)	6.8±6.9	5.4±4.4	7.3±7.6	.341
SF36 PH (0–100)	67.7±21.3	69.5±22.8	66.9±20.9	.687
SF36 MH (0–100)	80.9±12.6	81.6±11	80.6±13.4	.800
SF36 Total (0–100)	74.3±15.3	75.5±15.9	73.8±15.2	.699
Physical performance factors				
Grip strength (kg)	25.8±9.1	35.5±9.9	21.8±4.6	<.001[**]
FT MTT (ms)	214.9±100.6	199.2±86.1	221.5±106.5	.462
SPPB (0–12)	10.2±1.8	10.2±2.0	10.2±1.7	.926
TUG (s)	9.7±2.0	9.5±2.2	9.7±1.9	.695
6MWT (m)	425.0±84.7	417.9±85.5	427.9±85.3	.702
Computerized single/dual tests				
CT CRT (ms)	1449.8±622.8	1288.0±431.0	1517.9±681.3	.219
MT CRT (ms)	1237.4±229.6	1202.3±213.9	1252.2±237.1	.471
DT CRT (ms)	1847.7±685.8	1812.6±696.5	1862.5±690.1	.810
MTI (%)	132.6±28.9	140.9±22.8	129.1±30.7	.171
CTI (%)	147.8±39.3	148.8±41.6	147.3±38.8	.901

[*] P < .05.
[**] P < .001.

6MWT = six-minute walk test, BFM = body fat mass, BMI = body mass index, CRT = reaction time of correct releases, CT CRT = correct response time of cognitive task, CTI = interference by cognitive task, DT CRT = correct response time of dual task, FSS = Fatigue Severity Scale, FT MTT = mean tap time of finger tapping, K-BDI = Korean version of Beck Depression Inventory, MMSE-KC = Mini-Mental State Examination in the Korean version of CERAD Assessment Packet, MT CRT = correct response time of motor task, MTI = interference by motor task, PPT = pain pressure threshold, SF36 PH/MH/Total = Short-Form Health Survey 36 Questions Physical Health/Mental Health/Total score, SMM = skeletal muscle mass, SPPB = short physical performance battery, TBW = total body water, TUG = Timed Up & Go test.

Table 2

Pearson correlation coefficients between MTI/CTI and various factors.

Variable	MTI (%)		CTI (%)	
	r	P value	r	P value
Baseline characteristics				
Age (y)	0.122	.380	0.436	<.001[**]
Education period (y)	0.226	.100	−0.249	.069
Farming period (y)	0.041	.769	0.290	.033[*]
Farm working time per year (h)	−0.182	.189	−0.156	.261
Housekeeping time per year (h)	−0.262	.055	−0.095	.494
Exercise time per year (h)	−0.004	.978	0.187	.175
Body composition				
SMM (kg)	−0.004	.978	−0.153	.268
BFM (kg)	−0.216	.116	−0.046	.743
TBW (ℓ)	−0.007	.958	−0.128	.357
BMI (kg/m^2)	−0.113	.417	−0.064	.646
Psycho-cognitive factors				
MMSE-KC (0–30)	0.062	.658	−0.329	.015[*]
CRT of Go/No-Go test (ms)	0.203	.141	0.670	<.001[**]
PPT (N)	0.077	.578	−0.043	.759
Stress (0–10)	0.158	.254	−0.162	.242
FSS (1–7)	0.162	.241	−0.152	.274
K-BDI (0–63)	−0.057	.682	−0.114	.413
SF36 PH (0–100)	−0.029	.833	−0.042	.763
SF36 MH (0–100)	−0.041	.767	−0.112	.420
SF36 Total (0–100)	−0.038	.787	−0.076	.586
Physical performance factors				
Grip strength (kg)	0.158	.253	−0.201	.144
FT MTT (ms)	−0.081	.562	0.195	.157
SPPB (0–12)	0.017	.905	−0.304	.026[*]
TUG (s)	−0.160	.247	0.364	.007[**]
6MWT (m)	0.197	.158	−0.170	.223

[*] $P < .05$.
[**] $P < .001$.

6MWT = six-minute walk test, BFM = body fat mass, BMI = body mass index, CRT = reaction time of correct releases, CTI = interference by cognitive task, FSS = Fatigue Severity Scale, FT MTT = mean tap time of finger tapping, K-BDI = Korean version of Beck Depression Inventory, MMSE-KC = Mini-Mental State Examination in the Korean version of CERAD Assessment Packet, MTI = interference by motor task, PPT = pain pressure threshold, SF36 PH/MH/Total = Short-Form Health Survey 36 Questions Physical Health/Mental Health/Total score, SMM = skeletal muscle mass, SPPB = short physical performance battery, TBW = total body water, TUG = Timed Up & Go test.

(r = 0.436, $P < .001$), farming period (r = 0.290, $P = .033$), MMSE-KC score (r = −0.329, $P = .015$), CRT of the Go/No-Go test (r = 0.670, $P < .001$), SPPB score (r = −0.304, $P = .026$), and TUG time (r = 0.364, $P = .007$).

3.3. Multiple linear regression analysis (stepwise) between CTI and various factors

Table 3 summarizes the results of the stepwise multiple linear regression analysis. Model I showed that the CRT of the Go/No-

Go test (β = 0.558, $P < .001$) was only significantly associated with CTI not MTI, reflecting the most explanatory factor. Besides, Model II revealed that the CRT of the Go/No-Go test (β = 0.536, $P < .001$) and the score of the MMSE-KC (β = −0.228, $P = 0.05$) were significantly associated with CTI. In model III, in addition to cognitive factors, annual exercise time was included, and CRT of Go/No-Go test (β = 0.518, $P < .001$), the MMSE-KC score (β = −0.343, $P = .006$), and exercise time per year (β = −0.274, $P = .03$) were significantly associated with CTI.

Table 3

Multiple linear regression analysis (stepwise) between CTI and various factors.

Model	Variable	CTI			
		R^2	B ± SE	Standardized β	P value
I	CRT of Go/No-Go test (ms)	0.311	0.160 ± 0.033	0.558	<.001[**]
II	CRT of Go/No-Go test (ms)	0.363	0.154 ± 0.033	0.536	<.001[**]
	MMSE (0–30)		−4.155 ± 2.066	−0.228	.050[*]
III	CRT of Go/No-Go test (ms)	0.424	0.148 ± 0.031	0.518	<.001[**]
	MMSE (0–30)		−6.254 ± 2.184	−0.343	.006[**]
	Exercise time per year (h)		−0.062 ± 0.027	−0.274	.026[*]

[*] $P < .05$.
[**] $P < .001$.

CRT = reaction time of correct releases, CTI = interference by cognitive task, MMSE-KC = Mini-Mental State Examination in the Korean version of CERAD Assessment Packet.

4. Discussion

In the present study, the DTI-related factors in healthy farmers were analyzed using a computerized experiment that can quantify DTI (Fig. 2), we found that the CTI, percent of DTI excluded interference by MT, was significantly related to CRT of Go/No-Go test, score of MMSE-KC, and annual exercise time in multiple linear regression model. This result can be referred to as a reaffirmation of reports of increased DTI for the elderly, neurological disabled persons with cognitive degradation.[4,5] In other words, improvement in cognitive function, attention, and response speed and proper exercise indicate that can reduce DTI, which increases with age, and improve daily activities and working performance.

In correlation analysis, more different factors have shown a significant correlation. In terms of baseline characteristics, age and farming period were shown to be related to CTI. In accordance with our results several previous studies also found that age was the most significant factor related to DTI. The increased DTI in older adults has also been evidenced by systematic research and reviews.[24–26] As with age, the farming period showed a significant positive correlation with CTI because the characteristics of the 2 were very similar. In terms of physical performance factors, the total SPPB score and the total time of the TUG test were significantly related to CTI. These results and previous studies that physical exercise interventions have been effective for gait-related DTI may support that physical performance function may also be an important relevant factor.[27] In terms of psycho-cognitive factors, as mentioned earlier, CTI was closely associated with total MMSE-KC scores and CRT of the Go/No-Go test. Individuals with neurological defects may be particularly vulnerable to DTI,[28] reflecting the importance of cognitive function. Additionally, most evidence for DTI occurrence has been derived from studies on people with neurological defects, such as Parkinson disease and Alzheimer disease,[29] stroke,[30] or older adults.[31] Regarding the previous studies about the effect of physical exercise and activity on cognitive function,[32] the relationship between physical and cognitive function were critical for healthy aging.[33] These results suggest that cognitive function and physical exercise should be considered as a necessity as a strategy for reducing DTI.

This is the second step of the HELPinFarm that development and scientific proving of coping strategies for agricultural working performance in Korean farmers, a cross-sectional study designed to serially prove the factors to related DTI based on quantitative individualized variables. This is a necessary study for an aging rural society. DTI is found in all ages, and it can be improved by changing the living environment, especially for the elderly, and may reduce daily activity-related accidents. Thus, DTI among older people should be considered separately because of its profound effects on daily performance and proving the DTI-related factors may be useful to determine the impact of DTI in aging societies. In terms of the application of study results and considering the modifiable individual characteristics, improving cognitive function is necessary for improving the daily life activities. So as a recommendation, lifestyle modification should be performed in the elderly depending on their age and cognitive/physical functional level.

There are some limitations to this study. For the closest association of CTI and attention, the cognitive task in DTI experiments and the Go/No-Go test may be similar measurements in that they require attention. Attention is the ability required to identify and respond to go or no-go signs on both tests.[34] Therefore, taking into potential bias, it may have the closest relevance during assessments. Additionally, Yang et al[35] clarified that, in previous studies, attention resources were more allocated with cognitive tasks than motor tasks. Therefore, the attention level for cognitive function may be related more to interference in DTI. It is necessary to look at the association between DTI and other cognitive details. In addition, this study is a cross-sectional study of small sample size, which investigated DTI-related factors through statistical analysis. In this regard for the reliability of the results of this study, further study on proof of concept with clinical evidence needs to be performed.

Nevertheless, there are several clinical and research strengths in how to derived results. The results of DTI measurements at a healthy stage without brain disease and not focused on the elderly could be a more sensitive screening marker. And, DTI was classified into CTI and MTI, showed a significant pattern only in CTI in this study. In the DT design, cognitive and motor tasks were implemented simultaneously, but the cognitive loading for each task was shown to differ by size and influence. Serial decomposition of DT has been proven in separate tasks that evaluated the effects of motor or cognitive tasks on DT.[11] Because quantitative individualized DTI, such as MTI and CTI, is based on different task loads, different patterns of related factors might be present. This study showed that only CTI was significantly related to several functions in the correlation and causality analysis, so our result is meaningful in understanding the relationship between cognitive function and cognitive load.

In conclusion, the attentional level in cognitive function is the most explanatory factor of decreasing DTI reflecting the relative implication. In the future, dual-task training focused on attention and proper exercise may be actively beneficial for the old people moreover than passive simplification and modification in lifestyles.

Author contributions

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