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Preliminary Study of the Physical Fitness Test for Screening of Cognitive Impairment in the Korean Elderly

Jhin-Yi Shin[1]
SungKyunKwan University, Republic of Korea, Researcher
Sungmin Oh[2*]
SungKyunKwan University, Republic of Korea, Researcher

Abstract

This study aimed to evaluate the usefulness of physical fitness measurement for cognitive dysfunction screening in elderly Koreans. The subjects of the study were 88 elderly people (16 males and 72 females) aged 60 years or older who visited the Gyeonggi-do public health center and hospital associated with the neurology department of a university hospital in Gyeonggi-do, agreed with the purpose of this study, and wished to participate. Physical fitness measurement variables were isometric muscle strength, muscular endurance, flexibility, cardiorespiratory endurance, agility and dynamic balance, and coordination, and cognitive function tests performed using K-RBANS(Korean-Repeatable Battery for the Assessment of Neuropsychological Status) and CDR(clinical dementia rating), which were dementia screening tools. As a data processing method, correlation analysis was conducted to analyze the correlation between physical fitness and cognitive function. By conducting Receiver Operating Characteristic (ROC) analysis, the diagnostic accuracy and optimal cut-off of each physical fitness test for cognitive impairment were defined as CDR 0.5. As a result of the study, the F8WT, TUG(Time Up & Go Test), and T-wall tests showed a large area under the curve (AUC) that defined cognitive impairment (TUG=.768, 95%CI=.650~.885; F8WT=.735, 95%). CI=.612~.857, T-wall=.682, 95% CI=.545~.819). The optimal cut-off for predicting cognitive impairment was 6.0 seconds in TUG (sensitivity = 73.2%, specificity = 73.1%), 26.3 seconds in F8WT (sensitivity = 71.4%, specificity = 73.1%), and T-wall. 94.5 seconds (sensitivity = 62.5%, specificity = 65.4%). The F8WT, TUG, and T-wall test were confirmed as accurate and convenient measurement methods for screening cognitive dysfunction in elderly Koreans. In addition, the availability for screening cognitive dysfunction in the elderly population with various levels of education was confirmed.

Key words: K-RBANS, CDR, cognitive disorder screening test, senior physical fitness test, dementia test

* Corresponding author
Email address: sungminoh@skku.edu

Introduction

The National Health Insurance Service defines 66 years old as an important transition period for health in aging, and has been conducting "medical benefit life-transition screening" for senior citizens aged 66 or older since 2018. Elderly checkups with high incidence after middle age are largely divided into general tests (i.e., questionnaire and examination, vision and hearing tests), gender and age tests (i.e., osteoporosis, depression, lifestyle assessment, cognitive dysfunction, and physical function tests) to detect and prevent health problems such as fall and cognitive abnormalities of the elderly.

The elderly's physical function test in the general health examination is evaluated by Time Up & Go Test (TUG), Romberg Test (i.e., open-eye single-foot standing, closed-eye), IADL, and fall experience. Cognitive function evaluation is performed by using KDSQ-C (Korean Dementia Screening Questionnaire-Cognition), a test tool for early detection of dementia as a neuropsychological factor.

Cases and previous studies applied to general health examination items verify the relationship between physical function, strength and cognitive function of the elderly, which is a neuropsychological factor, and the possibility of physical examination items for early detection of dementia is raised. Alfaro-Acha et al. (2007) and Fitzpatrick et al. (2007) studied healthy elderly people without neuropsychological cognitive impairment and suggested that walking speed can be used as a sensitive tool to predict cognitive function. And as a result of examining the relationship between muscle strength and cognitive function in the study by Buchaman et al. (2007) and Boyle et al. (2009), it was reported that weakness in muscle strength increases the risk of dementia, and suggests that muscle strength can predict the risk of dementia in advance. A study by Kueper et al. (2017) also found that the upper and lower extremity motor functions were significantly related to the increased risk of neuropsychological factors. In addition, a meta-analysis study examining the relationship between physical function, strength, and cognitive function in healthy elderly reported that people with high physical functional abilities such as walking speed, lower extremity function, and balance had good overall cognitive function, executive function, memory, and task processing speed (Demnitz et al., 2016). A study examining the relationship between exercise ability and cognitive function in 696 dementia patients also suggested that measuring exercise ability could predict the risk of neuropsychological cognitive decline (dementia) because the higher the degree of dementia, the lower the exercise ability (Sverdrup et al., 2018).

According to previous studies, muscle strength, walking speed, and athletic ability are significantly related to the decline in neuropsychological cognitive function, and the possibility that physical strength can be used as an evaluation tool to predict risk was confirmed. Therefore, if an individual's physical strength level can be known to what level it is related to the risk of cognitive decline of neuropsychological factors, it is thought that it will help prevent dementia by predicting the degree of cognitive function in advance. Most of the previous studies examining the relationship between physical strength and cognitive function were conducted by applying a single item such as balance, gait, and muscle strength as physical function and physical strength test tools, and many studies were mainly conducted on Westerners. Therefore, it is necessary to examine the relationship between cognitive function in consideration of general health examination items in generall and national physical fitness 100 fitness items applied to the elderly in Korea based on the Senior Fitness Test (SFT) which is fucused on the Korean elderly population since Asian’s physique variables and standards are different from the Caucasian or African-american’s.

Therefore, this study first attempts to find out the convergent validity by examining the correlation between cognitive function and SFT items of subjects with various cognitive function levels such as subjective memory disorder and mild cognitive disorder. Next, by verifying the accuracy of diagnosis cognitive functions of neuropsychological factors, an appropriate physical reference could be set up. It is thought that the physical fitness standards verified in this study can be used as a fundamental study to induce physical activity and fitness level improvement to prevent dementia in the actual life field.

Methods

Subjects

Since this study aims to predict neuropsychological cognitive dysfunction using physical fitness standards, the study subjects were selected excluding elderly people aged 60 or older diagnosed with moderate dementia or higher. Accordingly, 88 elderly people aged 60 or older (16 males and 72 females) who voluntarily agree with the purpose of this study for check-up own cognitive ability with their previlege, and were selected as convenience sampling methods. <Table 1> shows the distribution by age classified into 5-year-old units of the subjects.

Table 1. Frequency of Research Subjects by Age

Age group (yrs)	Normal		SMI & MCI	
	n	%	n	%
60-64	5	5.7	9	10.2
65-69	8	9.1	10	11.4
70-74	14	15.9	17	19.3
75-79	10	11.4	15	17.0
Total (n=88)	37	42.0	51	58.0

Variables

1) Anthropometric and Senior physical fitness

The Senior Fitness Test (SFT) developed by Rikli and Jones at the University of California (USA) in 2001, is a method designed to measure physiological variables necessary for independent functioning and physical mobility in older adults. It has become the most commonly used measure because it does not require special equipment, is easy to perform and score, and has certain safety characteristics. It consists of the Chair Stand Test for lower extremity muscle strength (muscular endurance), the Biceps Curl Test or grip strength for upper extremity muscle strength, the Chair Sit and Reach Test for lower extremity flexibility, the Back Scratch Test for upper extremity flexibility, the Timed Up-and-Go Test for agility-dynamic balance, and the 2-minute step test or 6-meter walk for cardiovascular endurance. In this study, the T-wall test and the 8-foot up-and-go test for lower extremity angular muscle strength and coordination were added. Table 2 shows The variables and items for measuring physique and body composition, and physical strength items measured by muscular strength, muscular endurance, flexibility, Cardiovascular endurance, agility·dynamic balance, and coordination based on the SFT. Measurement methods were adapted from The senior fitness test manual by Rikli & Jones (2013).

Table 2. Variables of Anthropometric and Senior Fitness

Variables		Measurement Items
Anthropometric	physique	height (cm)
		weight (kg)
	body composition	% body fat (%), BMI (kg/m2)
Senior Fitness	muscular strength	grip strength (kg) leg strength (kg)
	muscular endurance	30-sec chair stand (rep)
	lower body flexibility	chair sit and reach test (cm)
	cardiovascular endurance	2-min step (rep)
	agility and dynamic balance	TUG (Timed Up-and-Go) test (sec)
	coordination	8-foot up and go test (sec) T-wall execution time (sec/100) T-wall matching number (num/100)

2) Neuropsychological assessment

For the cognitive function test, the CDR scale and K-RBANS, which are dementia screening tools, were used.

① K-RBANS(Korean-Repeatable Battery for the Assessment of Neuropsychological Status)

K-RBANS has been adapted from the existing RBANS and has been developed to predict the need for repeated tests and the detection and characteristics of cognitive deficiency (Kwak et al., 2018). The test items consist of 12 sub-examinations of five items: immediate memory, space-time composition ability, language ability, attention, and delayed memory. The sub-test consists of word list learning, storytelling recall, drawing shapes, lineage, waiting for picture names, memorizing numbers, and writing symbols, and the higher the score, the better the cognitive function (Kelly et al., 2019). In this study, the test period was less than 30 minutes to maximize patient cooperation and minimize fatigue effects on performance, and the difficulty was applied to the normal youth group and the moderate dementia group. Since it is difficult to diagnose the level of cognitive function only with neuropsychological tests, the level of cognitive function is generally diagnosed through the results of neuropsychological tests and medical treatment by a specialist. Therefore, in this study, based on the K-RBANS test score, data treated by clinical specialists for normal cognitive function, subjective memory disorder (SMI), and mild cognitive impairment (MCI) were used.

② CDR (Clinical Dementia Rating)

Clinical Dementia Rating (CDR) is a tool developed by Hughes et al., (1982) and uses a rating scale that measures the overall degree of the cognitive and social function of dementia patients. CDR consists of evaluating six detailed items: memory, orientation, judgment and problem-solving skills, community affairs, home and hobbies, and personal care to evaluate cognitive and social functional areas of dementia evenly. The examiner evaluates the functionality of these six items through detailed interviews with patients and carers, and gives each item a score from 0 to 3 points (0, 0.5, 1, 2, 3). CDR 0 points are normal (not dementia), CDR 0.5 points are subjective memory impairment and mild cognitive impairment, CDR 1 point is moderate and severe, CDR 2 points are very severe, and CDR 3 points terminal dementia. In the study of Choi et al., (2001), the reliability of the CDR scale between inspectors of each of the six items was verified as Kappa = 0.86~1. CDR cognitive function scores were classified into 0-point normal groups, 0.5-point subjective memory impairment (SMI), and mild cognitive impairment (MCI).

Statistical Analysis

The data were analyzed with the SPSS Ver.25.0 statistical program. First, Pearson's correlation (r) analysis was conducted to find out the relationship between the level of K-RBANS cognitive function and the physical strength and body composition variables, and the convergent validity was verified through this. Second, ROC curve analysis was conducted to verify the accuracy of the fitness criteria for cognitive function classification and to present a cut-off point that can predict the risk of neuropsychological cognitive dysfunction. The accuracy of classification according to the fitness criteria was recognized by the area under the ROC curve (AUC), and the fitness reference point was presented by checking the sensitivity (the probability of judging that there is no disease) and specificity (the probability of judging that there is no disease). The AUC accuracy verification criteria were fail (AUC = 0.5), poor (0.5 < AUC 0 0.7), fair (0.7 < AUC 0 0.9), good (0.9 < AUC 1 1.0), and excellent (AUC = 1.0), (Swetin, 1988). All statistical significance levels in this study are α=.05.

Results

The Relations between the Factors

In this study, the results of correlation analysis to find out the relations between the level of cognitive function and body composition, and physical strength according to the group are as follows.

1) Relationship between age, body composition factors, and cognitive function factors

(1) Relationship between age, body composition factors, and cognitive function between groups according to K-RBANS diagnosis.

As shown in <Table 3>, in the case of a normal group, age was negatively related to immediate memory (*r*=-.300), attention (*r*=-.382), and delay memory (*r*=-.264). The height were positively related to the total score of the RBANS test (*r*=-.232), spacetime/composition skills (*r* =.215), attention (*r*=.359), and delay memory (*r*=.254), while negatively related to language skills (*r*=-.239). Weight showed a positive relationship with immediate memory (*r*=.256), attention (*r*=.246), delayed memory (*r* =.249), and negative relationship with language skills (*r*=-.235). BMI showed a positive relationship with immediate memory (*r*=.203). Body fat rate did not correlated with cognitive functional factors. In the case of the SMI, age showed a negative relationship with the total RBANS test score (*r*=-.570), immediate memory (*r*=-.456), spacetime/composition skills (*r*=-.268), language skills (*r*=-.397), attention (*r*=-.538), delay memory (*r*=-.406). The height showed a positive relationship with spacetime/composition skills (*r*=.265). There was no correlation between weight and BMI with cognitive function. The body fat rate showed a negative relationship with the total score of the RBANS test (*r*=-.279), immediate memory (*r*=-.255) and attention (*r*=-.368). In the case of the MCI, age showed a negative relationship with the total RBANS test score (*r*=-.200), immediate memory (*r*=-.264) and delayed memory (*r*=-.211). Height showed a positive relationship with RBANS test total score (*r*=.397), spacetime/composition skills (*r*=.475), attention (*r*=.475), and delay memory (*r*=.475). Weight showed a positive relationship with RBANS test total score (*r*=.242), spacetime/composition skills (*r*=.243), attention (*r*=299), and delayed memory (*r*=.296). BMI did not correlate with cognitive function factors.

The body fat rate was negatively correlated with the total score of the RBANS test (*r*=-.363), spacetime/composition skills (*r*=-.349), attention (*r*=-.390), and delay memory (*r*=-.218).

Table 3. Correlation analysis between Neuropsychological factors and anthropometric by K-RBANS diagnosis group

Group	Variables	RBANS total score	RBANS immediate memory	RBANS spacetime /compositio n skills	RBANS language skills	RBANS attention	RBANS delayed memory
Normal	Age (yrs)	-.178	-.300	.183	.155	-.382*	-.264
	height (cm)	.232	.145	.215	-.239	.359*	.254
	weight (kg)	.165	.256	.060	-.235	.246	.249
	BMI (kg/m2)	.009	.203	-.100	-.112	-.005	.119
	bodyfat (%)	-.022	.082	-.062	.012	-.099	.049
SMI	Age (yrs)	-.570**	-.456**	-.268	-.397*	-.538**	-.406*
	height (cm)	.127	.035	.265	.140	.130	-.170
	weight (kg)	.087	.131	.159	-.033	-.004	.056
	BMI (kg/m2)	.021	.131	.002	-.123	-.089	.190
	bodyfat (%)	-.279	-.255	-.182	-.125	-.368*	-.004
MCI	Age (yrs)	-.200	-.264	-.034	-.094	-.166	-.211
	height (cm)	.397	.140	.475*	.006	.524*	.302
	weight (kg)	.242	.093	.243	-.024	.299	.296
	BMI (kg/m2)	-.022	.004	-.084	-.061	-.043	.139
	bodyfat (%)	-.363	-.177	-.349	-.190	-.390	-.218

**p<.01, **p<.001*

(2) Relationship between age, body composition factors, and cognitive function factors by group according to CDR diagnosis

<Table 4> shows the correlation results between age, body composition factors, and cognitive function factors by group according to Clinical Dementia Rating (CDR). CDR are classified into normal 0, and subjective memory impairment or mild cognitive impairment 0.5 respectively. For group 0, the age had a negative correlation with RBANS total score (*r*=-.527), immediate memory (*r*=-.566), language skills (*r*=-.345), attention (*r*=-.536), delay memory (*r*=-.512). Height showed a positive relationship with RBANS total score (*r*=.232), immediate memory (*r*=.219), spacetime/composition skills (*r*=.366), and attention (*r*=.278). Weight showed a positive relationship with immediate memory (*r*=.285), spacetime/composition skills (*r*=.206), attention (*r*=.239), and a negative relationship with

language skills (*r*=-.215). BMI did not correlate with cognitive functional factors. The body fat rate showed a negative relationship with the total score of the RBANS test (*r*=-.204), spacetime/composition skills (*r*=-.232), and attention (*r*=-.303). In the case of the 0.5 group, age showed a negative relationship with attention (*r*=-.240). Height showed a positive relationship with RBANS test total score (*r*=.312), spacetime/composition skills (*r*=.290), and attention (*r*=.410). The weight showed a positive relationship with the total RBANS test score (*r*=.227) and delayed memory (*r*=.220). There was no correlation between BMI and body fat rate with cognitive functional factors.

Table 4. Correlation analysis between Neuropsychological factors and anthropometric by CDR diagnosis group

Group	Variables	RBANS total score	RBANS immediate memory	RBANS spacetime /composition	RBANS language skills	RBANS attention	RBANS delayed memory
normal (0)	Age (yrs)	-.527**	-.566**	-.136	-.345	-.536**	-.512**
	height (cm)	.232	.219	.366	-.130	.278	.172
	weight (kg)	.163	.285	.206	-.215	.239	.139
	BMI (kg/m2)	.000	.173	-.063	-.144	.025	.038
	bodyfat (%)	-.204	-.060	-.232	-.050	-.303	-.117
cognitive (0.5)	Age (yrs)	-.190	-.195	-.109	.067	-.240	-.172
	height (cm)	.312*	.125	.290*	.151	.410**	.132
	weight (kg)	.227	.190	.163	.053	.191	.220
	BMI (kg/m2)	.080	.158	.011	-.027	-.034	.192
	bodyfat (%)	-.054	-.011	-.091	-.020	-.149	.102

**p<.01, **p<.001*

2) Relationship between Physical Fitness Factors and Cognitive Functional Factors

(1) Relationship between age, body composition, and physical fitness between groups according to K-RBANS diagnosis

<Table 5> shows the relationship between physical fitness and cognitive function between groups according to K-RBANS diagnosis. In the case of the normal group, the relative grip strength showed a positive relationship with the RBANS total score (*r*=.251) and attention (*r*=.242). The lower body flexibility had a negative relationship with total RBANS test score (*r*=-.254), spacetime/composition skills (*r*=-.479), attention (*r*=-.309). The 30 seconds chair stand showed a positive relationship with the total RBANS test score (*r*=.212), immediate memory (*r*=.347), and delayed memory (*r*=.244). The 2 minutes step did not show any correlation with cognitive functional factors. TUG test showed a negative relationship with attention (*r*=-.267). 8-foot up-and-go test showed a negative relationship

with immediately memory (*r*=-.219), attention (*r*=-.304), and a positive relationship with language skills (*r*=.220). The T-wall time had negative relationships with the RBANS total score (*r*=-.399), immediate memory (*r*=-.389), and attention (*r*=-.442). T-wall matching did not show any correlation between cognitive function factors. Leg strength L_E showed positive relationship with RBANS total score (*r*=.265), immediate memory (*r*=.403), attention (*r*=.246), and delayed memory (*r*=.405). Leg strength L_F showed positive relationship with RBANS total score (*r*=.312), immediate memory (*r*=.338), attention (*r*=.381), and delayed memory (*r*=.338). Leg strength R_E showed a positive relationship with RBANS total score (*r*=.361), immediate memory (*r*=.343), attention (*r*=.328), and delayed memory (*r*=.543). Leg strength R_F showed a positive relationship with RBANS total score (*r*=.489), immediate memory (*r*=.538), attention (*r*=.525), and delayed memory (*r*=.385). In the case of the subjective memory impairment group (SMI), relative grip strength showed a positive relationship with RBANS total score (*r*=.386), spacetime/composition skills (*r*=.434), language skills (*r*=.219), and attention (*r*=.463). The lower body flexibility showed a negative relationship wite delayed memory (*r*=.224). The 30 seconds chair stand showed a positive relationship with RBANS total score (*r*=.455), immediate memory (*r*=.401), language skills (*r*=.417), attention (*r*=.523), and delayed memory (*r*=263). The 2 minutes step showed a positive relationship with RBANS total score (*r*=.424), immediate memory (*r*=.240), spacetime/composition skills (*r*=.273), language skills (*r*=.307), attention (*r*=.434), and delayed memory (*r*=.239). TUG test showed a negative relationship with RBANS total score (*r*=-.564), immediate memory (*r*=-.494), language skills (*r*=-.509), attention (*r*=-.618), delayed memory (*r*=-.276). 8-foot up-and-go test showed a negative relationship with the RBANS total score (*r*=-.438), immediate memory (*r*=-.381), language skills (*r*=-.488), attention (*r*=-.499), delay memory (*r*=-.221). The T-wall time had negative relationships with the RBANS total score (*r*=-.487), and immediate memory (*r*=-.427), language skills (*r*=-.349), attention (*r*=-.497), and delayed memory (*r*=-.289). T-wall matching showed a negative correlation with the RBANS total score (*r*=.335), spacetime/composition skills (*r*=.200), language skills (*r*=.462), and attention (*r*=.355). Leg strength L_E showed a positive relationship with RBANS total score (*r*=.390), immediate memory (*r*=285), language skills (*r*=.381), and attention (*r*=.457). Leg strength L_F showed a positive relationship with RBANS total score (*r*=.354), spacetime/composition skills (*r*=240), and attention (*r*=.499). Leg strength R_E showed a positive relationship with RBANS total score (*r*=.387), immediate memory (*r*=253), language skills (*r*=.346), and attention (*r*=.437). Leg strength R_F showed a positive relationship with RBANS total score (*r*=.286), spacetime/composition skills (*r*=.245), and attention (*r*=.350). In the case of the mild cognitive impairment group (MCI), relative grip strength showed a positive relationship with RBANS total score (*r*=.384), spacetime/composition skills (*r*=.298), language skills (*r*=.321), and attention (*r*=.519). The lower body flexibility showed a positive relationship with language skills (*r*=.264) and attention (r=.212), and showed a negative relation with delayed memory (r=-.307). The 30 seconds chair stand showed a positive relationship with RBANS total score (r=.276), immediate memory (r=.202), language skills (r=.354), and delayed memory (r=.352). The 2 minutes step showed a positive relationship with RBANS total score (r=.257), language skills (r=.238), and attention (r=.343). TUG test showed a negative relationship with RBANS total score (r=-.286), spacetime/composition skills (r=-.343), language skills (r=-.277), and attention (r=-.238). 8-foot up-and-go test showed a negative relationship with the RBANS total score (r=-.220), language skills (r=-.254), delayed memory (r=-.213). The T-wall time had negative relationships with the total RBANS score (r=-.357), immediate memory (r=-.333, attention (r=-.282), and delayed memory (r=-.384). T-wall matching showed a positive correlation with the RBANS total score (r=.552), immediate memory (r=.520), spacetime/composition skills (r=.504), attention (r=.585), and delayed memory (r=.390). Leg strength L_E showed a positive relationship with RBANS total score (r=.364), spacetime/composition skills (r=264), attention (r=.453), and delayed memory (r=.364). Leg strength L_F showed a positive relationship with RBANS test total score (r=.364), spacetime/composition skills (r=247), language skills (r=.213), attention (r=.456), and delayed memory (r=.329). Leg strength R_E showed positive relationship with the RBANS total score (r=.228), attention (r=.314), and delayed memory (r=.204). Leg strength R_F showed a positive relationship with RBANS total score (r=.419), spacetime/composition skills (r=.281), language skills (r=.246), attention (r=.432), and delayed memory (r=.468).

Table 5. Correlation analysis between Neuropsychological factors and physical fitness by K-RBANS diagnosis group

Group	Variables	RBANS total score	RBANS immediate memory	RBANS spacetime /composition	RBANS language skills	RBANS attention	RBANS delayed memory
Normal	Relative grip strength (%)	.334**	.143	.327**	.222*	.428**	.128
	lower body flexibility (cm)	.148	.082	.066	.268*	.037	.135
	30 sec chair stand (rep)	.309**	.327**	.030	.295**	.302**	.248*
	2 min step (rep)	.390**	.277**	.263*	.313**	.363**	.283**
	TUG test (sec)	-.357**	-.291**	-.161	-.261*	-.449**	-.196
	8-foot up-and-go test (sec)	-.330**	-.272*	-.108	-.275**	-.380**	-.233*
	T-wall time (sec/100)	-.532**	-.492**	-.300**	-.331**	-.466**	-.453**
	T-wall match (num/100)	.266*	.192	.232*	.130	.351**	.096
	leg strength L_E (kg)	.298**	.245*	.135	.124	.390**	.214*
	leg strength L_F (kg)	.239*	.131	.160	.033	.418**	.123

Group	Variables	RBANS total score	RBANS immediate memory	RBANS spacetime /composition	RBANS language skills	RBANS attention	RBANS delayed memory
	leg strength R_E (kg)	.243*	.147	.117	.133	.349**	.155
	leg strength R_F (kg)	.286**	.188	.221*	.042	.390**	.206
SMI	Relative grip strength (%)	.103	.045	-.101	.233	.349	-.083
	lower body flexibility (cm)	-.033	-.138	-.020	.050	.041	-.056
	30 sec chair stand (rep)	.068	.021	-.189	.391	.263	-.134
	2 min step (rep)	.274	.227	.374	.360	.296	-.099
	TUG test (sec)	-.331	-.304	-.135	-.142	-.655**	-.080
	8-foot up-and-go test (sec)	-.007	-.013	.249	-.109	-.298	.139
	T-wall time (sec/100)	-.441	-.475	-.210	-.293	-.371	-.419
	T-wall match (num/100)	.379	.421	.382	.148	.476	.080
	leg strength L_E (kg)	.144	.115	-.105	.140	.329	.091
	leg strength L_F (kg)	-.238	-.161	-.489	-.223	.083	-.204
	leg strength R_E (kg)	-.145	-.168	-.358	-.078	.081	-.084
	leg strength R_F (kg)	-.054	-.058	-.180	-.067	.054	.017
MCI	Relative grip strength (%)	.379**	.175	.344**	.331**	.355**	.220
	lower body flexibility (cm)	.269*	.188	.183	.318**	.134	.207
	30 sec chair stand (rep)	.351**	.405**	.043	.291*	.293*	.328**
	2 min step (rep)	.413**	.293*	.240*	.314**	.374**	.353**
	TUG test (sec)	-.344**	-.298*	-.105	-.308**	-.381**	-.223
	8-foot up-and-go test (sec)	-.366**	-.323**	-.106	-.317**	-.364**	-.292*
	T-wall time (sec/100)	-.541**	-.514**	-.268*	-.368**	-.445**	-.477**
	T-wall match (num/100)	.242**	.107	.215	.124	.352**	.103
	leg strength L_E (kg)	.340**	.350**	.066	.233	.304**	.341**
	leg strength L_F (kg)	.384**	.260*	.252*	.185	.443**	.277*
	leg strength R_E (kg)	.332**	.275*	.107	.286*	.310*	.275*
	leg strength R_F (kg)	.398**	.323**	.242*	.154	.414**	.346**

*$p<.01$, **$p<.001$

(2) Relationship between age, body composition, and physical fitness between groups according to CDR diagnosis.

<Table 6> shows the relationship between physical fitness and cognitive function factors between groups according to Clinical Dementia Rating (CDR). In the case of the 0 groups, relative grip strength showed a positive relationship with RBANS total score (r=.492), immediate memory (r=.386), spacetime/composition skills (r=.460), and language skills (r=.430), and negative relationship with

attention (*r*=.203). The 30 seconds chair stand showed a positive relationship with RBANS total score (*r*=.413), immediate memory (*r*=.332), language skills (*r*=.457), attention (*r*=.320), and delayed memory (*r*=.359). The 2 minutes step showed a positive relationship with RBANS test total score (*r*=.533), immediate memory (*r*=.414), spacetime/composition skills (*r*=.313), language skills (*r*=.578), attention (*r*=.399), and delayed memory (*r*=.436). TUG was negatively related to RBANS total score (*r*=-.644), immediate memory (*r*=-.576), spacetime/composition skills (*r*=-.422), language skills (*r*=-.516), attention (*r*=-.530), and delayed memory (*r*=-.504). 8-foot up-and-go test showed a negative relationship with the total score of the RBANS (*r*=-.614), immediate memory (*r*=-.476), spacetime/composition skills (*r*=-.422), language skills (*r*=-.508), attention (*r*=-.477), delayed memory (*r*=-.543). The T-wall time showed a negative relationship with the total RBANS score (*r*=-.639), immediate memory (*r*=-.673), spacetime/composition skills (*r*=-.343), language skills (*r*=-.547), attention (*r*=-.460), delayed memory (*r*=-.542). The T-wall matching showed a positive relationship with attention (*r*=.261). Leg strength L_E showed a positive relationship with RBANS total score (*r*=.272), immediate memory (*r*=.261), and attention (*r*=.357). Leg strength L_F showed a positive relationship with RBANS total score (*r*=.264), immediate memory (*r*=.349), spacetime/composition skills (*r*=.230), and attention (*r*=.433). Leg strength R_E showed a positive relationship with RBANS test total score (*r*=.345), immediate memory (*r*=.288), spacetime/composition skills (*r*=.298), attention (*r*=.315), and delayed memory (*r*=.294). Leg strength R_F showed a positive relationship with RBANS total score (*r*=.259), immediate memory (*r*=.329), and attention (*r*=.374). In the case of the 0.5 group, relative grip strength showed a positive relationship with RBANS total score (*r*=.232), spacetime/composition skills (*r*=.260), language skills (*r*=.207), and attention (*r*=.348). The lower body flexibility and the 30 seconds chair stand had no correlation with cognitive functional factors. The 2-minute step showed a positive relationship with RBANS total score (*r*=.234), spacetime/composition skills (*r*=.203), and attention (*r*=.261). TUG showed a negative relationship with attention (*r*=-.320), while the 8-foot up-and-go test showed a negative relationship with attention (*r*=-.259). The T-wall time had a negative relationship with the RBANS total score (*r*=-.428), immediate memory (*r*=-.353), spacetime/composition skills (*r*=-.251), attention (*r*=-.411), and delayed memory (*r*=-.363). The T-wall matching showed a positive relationship with RBANS total score (*r*=.326), immediate memory (*r*=.251), spacetime/composition skills (*r*=.311), and attention (*r*=.399). Leg strength L_E showed a positive relationship with the RBANS total score (*r*=.279) and attention (*r*=.389). Leg strength L_F showed a positive relationship with attention (*r*=.382), while Leg strength R_E showed a positive relationship with attention (*r*=.299). Leg strength R_F showed a positive relationship with RBANS total score (*r*=.302), spacetime/composition skills (*r*=.249), attention (*r*=.413), and delayed memory (*r*=.221).

Table 6. Correlation analysis between Neuropsychological factors and physical fitness by CDR diagnosis group

Group	Variables	RBANS total score	RBANS immediate memory	RBANS spacetime /composition	RBANS language skills	RBANS attention	RBANS delayed memory
normal (0)	Relative grip strength (%)	.492**	.386*	.460*	.200	.557**	.307
	lower body flexibility (cm)	.075	-.012	-.063	.430*	-.203	.182
	30 sec chair stand (rep)	.413*	.332	.172	.457*	.320	.359
	2 min step (rep)	.533**	.414*	.313	.578**	.399*	.436*
	TUG test (sec)	-.644**	-.576**	-.422*	-.516**	-.530**	-.504**
	8-foot up-and-go test (sec)	-.614**	-.476**	-.422*	-.508**	-.477**	-.543**
	T-wall time (sec/100)	-.639**	-.673**	-.343	-.547**	-.460*	-.542**
	T-wall matching (num/100)	.132	.024	.026	.118	.261	.048
	leg strength L_E (kg)	.272	.261	.136	.082	.357	.181
	leg strength L_F (kg)	.264	.349	.230	-.147	.433*	.117
	leg strength R_E (kg)	.345	.288	.298	.123	.315	.294
	leg strength R_F (kg)	.259	.329	.113	.019	.374	.147
cognitive (0.5)	Relative grip strength (%)	.232	-.011	.260*	.207	.348**	.013
	lower body flexibility (cm)	.109	.038	.090	.105	.100	.049
	30 sec chair stand (rep)	.071	.165	-.128	.051	.138	.051
	2 min step (rep)	.234	.108	.203	.114	.261*	.140
	TUG test (sec)	-.100	-.037	-.008	-.028	-.320*	.041
	8-foot up-and-go test (sec)	-.112	-.086	.049	-.090	-.259*	-.032
	T-wall time (sec/100)	-.428**	-.353**	-.251	-.159	-.411**	-.363**
	T-wall matching (num/100)	.326*	.251	.311*	.114	.399**	.093
	leg strength L_E (kg)	.279*	.194	.115	.107	.389**	.201
	leg strength L_F (kg)	.179	-.029	.108	.085	.382**	.082
	leg strength R_E (kg)	.106	-.017	.003	.069	.299*	.020
	leg strength R_F (kg)	.302*	.132	.249	.037	.413**	.221

*$p<.01$, **$p<.001$

Physical Fitness Criteria for Predicting the Risk of Dementia and Mild Cognitive Impairment

1) Selection of fitness criteria using ROC curves

(1) Cognitive function prediction physical fitness criteria using K-RBANS diagnosis

Looking at the AUC value used as an indicator of the accuracy of the determination by the ROC curve for physical fitness according to the K-RBANS diagnosis, the most inaccurate figure was 0.304 in the 2 min step, and the most accurate figure was T-wall time as 0.736. The cut-off, which is determined by the maximum sum of sensitivity and specificity to select the reference point for physical fitness factors that cause subjective memory impairment and mild cognitive impairment, was selected the T-wall time of 98.3 seconds was selected as the reference point <Table 7>.

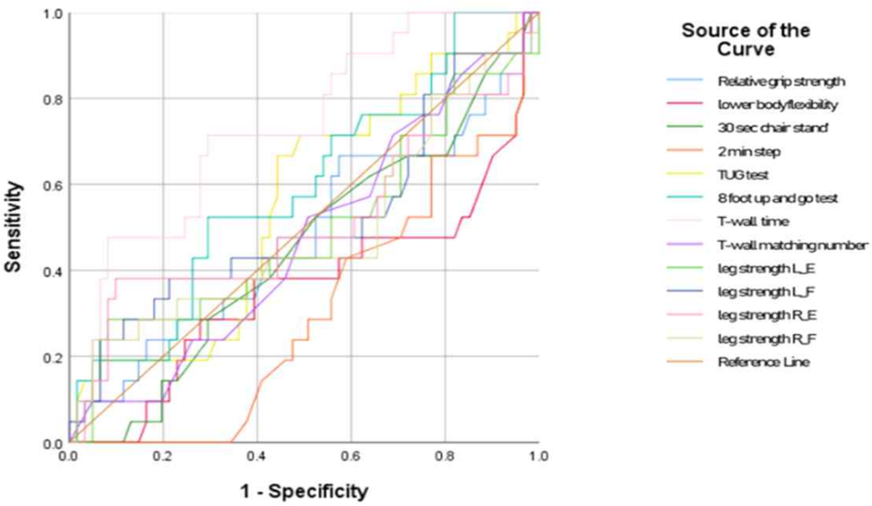

Figure 1. ROC Analysis Curve Based on K-RBANS Diagnosis

Table 7. Results of ROC analysis according to K-RBANS diagnosis

Test Result Variables	Area	Std. Error	Asymptotic Sig. b	Asymptotic 95% CI	
				Lower Bound	Upper Bound
Relative grip strength	0.477	0.078	0.754	0.323	0.631
lower body flexibility	0.360	0.076	0.057	0.211	0.510
30 sec chair stand	0.450	0.072	0.497	0.309	0.591
2 min step	0.304	0.061	0.008	0.185	0.424
TUG test	0.556	0.072	0.447	0.416	0.696
8-foot up-and-go test	0.590	0.071	0.222	0.450	0.730
T-wall time	0.736	0.062	0.001	0.615	0.857
T-wall matching number	0.473	0.072	0.714	0.332	0.614
leg strength L_E	0.491	0.080	0.907	0.335	0.648
leg strength L_F	0.519	0.080	0.799	0.361	0.676
leg strength R_E	0.516	0.083	0.828	0.353	0.679
leg strength R_F	0.489	0.081	0.886	0.332	0.647

Selected fitness variable	AUC	95% CI		cut-off	Sensitivity	Specificity
		Lower	Upper			
T-wall time	0.736	0.615	0.857	98.33	.714	.705

(2) Cognitive function prediction physical fitness criteria using CDR diagnosis.

Looking at the AUC value used as an indicator of the accuracy of prediction by the ROC curve for physical fitness according to CDR diagnosis, 30-sec chair stand showed the most inaccurate value of 0.272, and 8-foot up-and-go test showed the most accurate value of 0.735. In addition, the TUG test and T-wall time were 0.735 and 0.682, respectively, showing accurate values<Figure 2>, <Table 8>. When looking at the cut-off, which is determined by the maximum sum of sensitivity and specificity, to find the reference point for physical fitness factors that cause subjective memory impairment and mild cognitive impairment, it was 6.03 seconds for the TUG test, 26.31 seconds for 8 foot-up and go test, and 94.51 seconds for T-wall time.

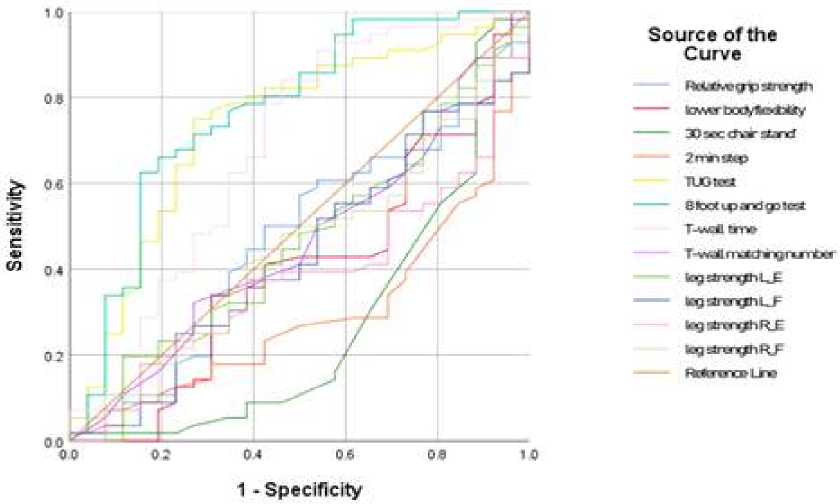

Figure 2. ROC analysis curve according to CDR diagnosis

Table 8. Results of Group normal (0) and Group cognitive (0.5) ROC analysis according to CDR diagnosis

Test Result Variables	Area	Std. Error	Asymptotic Sig. b	Asymptotic 95% CI	
				Lower Bound	Upper Bound
Relative grip strength	0.473	0.068	0.698	0.339	0.607
lower body flexibility	0.404	0.069	0.163	0.269	0.539
30 sec chair stand	0.272	0.067	0.001	0.141	0.403
2 min step	0.294	0.059	0.003	0.178	0.409
TUG test	0.735	0.062	0.001	0.612	0.857
8-foot up-and-go test	0.768	0.060	0.000	0.650	0.885
T-wall time	0.682	0.070	0.008	0.545	0.819

Test Result Variables	Area	Std. Error	Asymptotic Sig. b	Asymptotic 95% CI	
				Lower Bound	Upper Bound
T-wall matching number	0.462	0.068	0.577	0.329	0.594
leg strength L_E	0.461	0.068	0.573	0.327	0.595
leg strength L_F	0.433	0.068	0.329	0.300	0.565
leg strength R_E	0.383	0.064	0.090	0.259	0.508
leg strength R_F	0.452	0.067	0.482	0.320	0.583

Selected fitness variable	AUC	95% CI		cut-off	Sensitivity	Specificity
		Lower	Upper			
TUG test	0.735	0.612	0.857	6.03	.732	.731
8-foot up-and-go test	0.768	0.650	0.885	26.31	.714	.731
T-wall time	0.682	0.545	0.819	94.51	.625	.654

Discussion and Conclusion

The purpose of this study was to analyze the relationship between cognitive function and physical strength of subjects with various cognitive function levels, such as subjective memory disorder and mild cognitive impairment, and to present a cut-off point that can predict dementia risk by verifying the accuracy of cognitive function classification and physical strength criteria. Pearson's was conducted to analyze the relationship between cognitive function, physical strength, and physical composition variables using the SPSS Ver.25.0 statistical program. In order to find a reference point where dementia risk occurs when physical strength is below a certain level, the cut-off level was presented through ROC corve analysis for each physical strength factor. The main results of the study are summarized as follows.

As a result of examining the relationship between physical strength and cognitive function in this study, it was confirmed that there is a correlation between most physical strength factors and cognitive function factors (r=.221~.428, -.233~-.532). Cardiopulmonary endurance, muscular strength, and muscular endurance showed a weak positive relationship with cognitive function factors (r=.214~.428, p<.05), in particular, muscle strength showed a significant relationship with attention (r=.428, p<.01). Cardiopulmonary endurance, muscle strength, and muscle endurance showed a weak-clear positive relationship with cognitive function factors (r=.214~.428, p<.05), in particular, muscle strength showed a clear static relationship with attention (r=.428, p<.01). In K-RBANS, attention tests consist of numerically memorizing and symbol writing, representing the examinee's ability to remember and manipulate the information presented visually and verbally in short-term memory stores. Among them, the ability to manipulate the presented information is known as the ability of the frontal lobe function of the brain to be involved. The strong relationship between muscle strength and these items suggests that strengthening muscle strength can specifically affect cognitive functions such as attention. According to a meta-analysis study by Ericsson et al. (2011), it was reported that studies that combine aerobic exercise and muscular exercise improved attention, processing speed, and working memory compared to studies that performed only aerobic exercise. As such, detailed factors of cognitive function seem to be specifically affected by the type of exercise, and a study on whether the reinforcement of related physical factors directly affects if sub-factors of cognitive function are problematic in the future is also necessary.

The T-wall test, which measures coordination, showed a clear negative relationship with most cognitive functional factors (r=.-300~-.532, p<.01). In other words, it was found that the faster the coordination task was performed, the higher the cognitive function score. Coordination refers to the human body's ability to perform exercise quickly and accurately to respond to constantly changing tasks. It is mainly affected by neural networks, and various cognitive functions are expected to be involved in the ability to perform movements voluntarily. Although it is difficult to directly compare studies on coordination in the elderly are limited, studies that reported the relationship between coordination and cognitive function in some children have been reported. van der Fels et al. (2015) reported similar results to this study because performance such as motor skills, bilateral coordination, and progress of exercise duration showed strong relationships with cognitive functions, and balance, muscular strength, and agility showed relatively weak relationships with cognitive functions. In addition, Best (2010) stated that exercise that shows a stronger relationship with cognitive function might have higher complexity, so high level of cognitive function will be required. Also, it was showed that the performance of exercise with less cognitive intervention would be relatively less related to cognitive function. These results seem to support the reasons for studies that showed improvement in physical strength but did not affect cognitive function after performing simple and repetitive exercises for some elderly with dementia and mild cognitive impairment for a certain period of time. Considering that coordination is highly related to cognitive function in the elderly, it is thought that tasks related to coordination should be included when performing or planning exercise programs for dementia prevention and delay.

As a result, it was confirmed that there was a certain relationship between physical factors and cognitive functional factors. These test items are expected to be a good tool for evaluating the risk of dementia. In addition, developing physical factors that are related to detailed factors of cognitive function is expected to have a beneficial effect on the relevant cognitive function. In the existing clinical neuropsychological test field, there was a tendency to focus on the final results of the test. However, the overall results were not abnormal, but there were problems with individual cognitive function factors, and in recent early stages, it has become an important research direction to find cases where individual cognitive function is abnormal and take quick intervention. The relationship between physical and cognitive function is expected to enable individual and specific exercise prescriptions when certain cognitive function problems occur, and in the field of physical fitness measurement, it is expected to contribute to dementia prevention and delay by early screening these items and recommending cognitive tests or motivating participation in exercise. In the future, it is also necessary to study whether the development of these detailed physical fitness factors induces the improvement of detailed cognitive factors.

Recently, many studies have been reported that suggest appropriate physical fitness standards for preventing health and aging. In the group of normal population, the interchangeable signals of muscle contraction and relaxation are transmitted through stimulation of the nearby joint with muscle spindle and Gorgi tendon organs, and in the elderly, while it is believed that the function of the body to recognize movement has deteriorated as the above interchange becomes difficult. It is predicted that as the cognitive decline of the musculoskeletal system progresses, the cognitive function of the brain will also occur sequentially (Smith, 2020). Looking at overseas studies, it is often analyzed using the ROC curve statistical method to set the appropriate level of physical strength that causes or prevents diseases for each physical strength factor. n this study, the ROC curve was calculated using a statistical program to find the level of physical strength with subjective memory impairment or mild cognitive impairment, and the cut-off values with the highest sensitivity and specificity without cognitive impairment were calculated by physical factors.

As a result of the study, the physical factors that can determine subjective memory or mild cognitive impairment showed high AUC values for accuracy of judgment only in 3m target return, figure 8 walk, and t-wall time (second), and sensitivity and specificity were also found to determine the disease. However, other physical factors could not secure the accuracy of the judgment, and sensitivity and specificity could not be adopted.

This is similar to a study that examined the appropriate physical strength level to prevent metabolic syndrome in previous studies and found no level to diagnose other physical fitness items except cardiopulmonary endurance as diseases (Moon Yeo Jin et al., 2012, Song Hong-sun et al., 2018). In the correlation of this study, the tasks requiring complexity (complexity of agility, dynamic balance, quickness), and coordination that showed relatively high correlation with cognitive function showed statistically reliable results. This means that only physical fitness factors that are highly related to cognitive function are highly related to cognition.

In conclusion, according to the results of this study, there was some possiblity to confirm the relationship between physical strength and cognitive function. It is thought that the test items that measure these physical fitness factors can be a good tool for screening the risk of dementia in the sports field. In the future, it is expected that it can be used as a motivation to recommend cognitive tests or participate in exercise if the condition is insufficient by using the trimmed value when measuring the elderly's physical strength at physical fitness sites such as National Physical Fitness 100 (Cassilhas, Viana, Grassmann, Santos, Santos, Tufik, & Mello, 2007). In addition, in clinical trials in the medical and health sectors, it can be referred to if there is difficult to diagnose due to the influence of academic background or illiteracy through related physical strength measurements in addition to the existing neuropsychological tests. On the other hand, since the T-wall test item seems to be able to be used as a sensitive tool for measuring cognitive function, it is necessary to collect and verify continuous data in addition to the elderly fitness measurement item in National Physical Fitness 100. However, the study has limitations such as small sample size, and gender ratio in the participation. Also it could has lower sensitivity or reliability but it is worth to investigate for convenient approach to check cognitive ability with lower cost. Finally, it seems necessary to study whether it induces improvement in the cognitive function when developing physical factors that are related to detailed factors of cognitive function in the future.

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