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Analysis of Predictive Factors for Cognitive Impairment in the Elderly using Logistic Regression and Decision Tree Analysis

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ABSTRACT

No studies have analyzed the path of predicting the experience of cognitive dysfunction by considering various characteristics in elderly, especially focusing on sleep duration. Thus, this study aimed to predict the experience of cognitive dysfunction according to sleep duration in older individuals. This cross-sectional study used data from 3,361 older individuals from the 2021 Community Health Survey (CHS). Participants were included in two groups according to their experience of cognitive dysfunction (yes or no). Sleep duration was categorized into the following three groups: lack of sleep(<6h), normal sleep (6 to <10h), and oversleep (≥10h). Decision tree and logistic regression analyses were used to identify factors related to cognitive dysfunction in elderly. According to the decision model, those who slept for ≥10h had depression and experienced the highest rate (89.2%) of cognitive dysfunction. In contrast, people aged 65-74 years with a lack of sleep or average sleep duration and low stress levels were the least likely to experience cognitive dysfunction (63.0%). Older individuals who were asleep for ≥10h and had depression showed the highest rate of cognitive dysfunction. Community-based programs to improve cognition in the elderly or healthcare providers caring for the elderly need to continuously assess and consider their age, sleep time, and depression to prevent and manage cognition dysfunction in elderly.

Keywords: aged; decision trees; cognitive dysfunction; Community Health Survey (CHS)

INTRODUCTION

As the average life expectancy is increasing, owing to the rapid rise in economic status and improvement in medical skills, the number of older individuals is rapidly increasing (Jo, 2009). In 2022, the population aged ≥65 years in South Korea exceeded 9 million, accounting for 17.5% of the total population (Statistics Korea, 2022). By 2025, South Korea will become a super-aged society, and the elderly are expected to account for 20.6% in 2025 (Statistics Korea, 2022).

Population aging causes problems for older individuals and society (Kim et al., 2003). In an aging society, older individuals suffer from loneliness, loss of roles, and diseases. In addition, society faces problems related to the older population, such as increased medical expenses and social welfare services (Kim et al., 2003). Health problems are recognized as huge problems, and older individuals are more likely to suffer from chronic diseases than young people (Jaul & Barron, 2017).

Among chronic diseases, many older adults have an increased risk of developing dementia (Lee & Seong, 2018). Worldwide, dementia occurs in one person every 3 seconds (Honghao et al., 2020). In parallel, the global prevalence of dementia is estimated to be approximately 5-10% in older adults(Clinical Research Center for Dementia, 2020). According to the dementia prevalence survey (Clinical Research Center for Dementia, 2020), the prevalence of dementia among Koreans aged 65 and older is 10.3%, estimated at 832,000 people. In addition, it is predicted that by 2050, 3.02 million people, accounting for 15.9% of the total elderly, will suffer from dementia. The cost of managing patients with dementia is a huge economic burden; particularly, the cost was 20.61 million won, accounting for 33.2% of the annual household income in 2020 (Ministry of Health and Welfare, 2020). To prevent and delay dementia, the onset and course of cognitive dysfunction that leads to dementia should be carefully monitored. Therefore, the detection of cognitive dysfunction plays a pivotal role in the early diagnosis of dementia (Hua et al., 2020). In addition, the identification of changeable risk factors related to cognitive dysfunction is urgently required (Hua et al., 2020).

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Several previous studies have reported a relationship between sleep and cognitive function. Sex, age, marital status, education level, and stroke were associated with cognitive decline in older individuals (Anderson et al., 2007; van Hooren et al., 2007; Wu et al., 2011: Seol et al.,; 2019). In addition, dietary intake, alcohol consumption, smoking, physical activity, depression, and the presence of social support were significantly related to cognitive dysfunction in older individuals (Kim et al., 2012; Y. Lee et al., 2010; Meller et al., 2020; Wu et al., 2011). Individuals with short and long sleep durations had a higher risk of cognitive decline than those with moderate sleep duration (Hua et al., 2020). Another study reported that older individuals with sleep duration of 0-6 h or >9 h showed higher cognitive dysfunction than those who slept for 6-9 h in the day (Gildner et al., 2014). Although many previous studies explored the relationship between sleep time and cognitive function in various age groups, this relationship should be explored, especially in the elderly. This is because changes in sleep time and cognitive function are prominent in the elderly (Ding et al., 2020).

However, no studies have analyzed the path of predicting the experience of cognitive dysfunction by considering various characteristics of older individuals, especially focusing on sleep duration. To fill this gap, this study was conducted to identify factors related to cognitive dysfunction in the elderly and construct a prediction model that considers various factors, with sleep duration as the main factor.

This study aimed to establish a path to predict the experience of cognitive dysfunction according to sleep duration in individuals aged ≥65 years using the decision tree analysis method.

METHOD

Study design

This cross-sectional study used secondary data analysis. This study used data from the 2021 Community Health Survey (CHS) provided by the Korea Disease Control and Prevention Agency (KDCA). The 2021 CHS was nationwide survey and conducted to collect data from the adult population aged 19 years or older. The data collection period spanned from August 16 to October 31, 2021. To gather the required information, households were selected and a guidebook was sent to them. After explaining the survey, participation was asked to fill out a consent form. In order to conduct survey, trained investigators visited the selected sample households and conducted one-on-one interviews. This data is anonymous and cannot identify specific individuals, corporations, or organizations. All detailed information for 2021 CHS is available in the 2021 CHS raw data usage guidelines (KDCA, 2022).

Participants

Among the total 7,745 participants in the 2021 CHS, the number of older adults (>65 years) was 3,375. Excluding 14 participants who did not indicate whether they had experienced cognitive dysfunction, this study used data from 3,361 participants. In this study, participants with experience of cognitive dysfunction were included in the yes group (n=935, 27.8%) and those with no experience of cognitive dysfunction were included in the no group (n=2,426, 72.2%).

Measurements

Descriptions of the variables used in this study were extracted from the 2021 guidelines for the use of raw data from the CHS (Korea Centers for Disease Control and Prevention, 2022). Each variable was classified according to the standards described in a previous study (Kim & Choi, 2023).

General characteristics

The general characteristic variables included age (65-74, 75-84, ≥85 years) (Choi et al., 2017), sex (male, female), location (city, province), health status (bad, average, good), life satisfaction (low, high), and marital status (single, married). Life satisfaction scores on a scale of 10, 5, or less were classified as low and 6 or more were classified as high.

Socioeconomic characteristics

Socioeconomic characteristics, educational level (high school graduate or lower, college graduate or higher), basic livelihood recipients (no, yes), and economic activity (no, yes) were included in this study.

Health behaviors

The variables of health behaviors were frequency of breakfast consumption (3-4/week, 5-7/week), smoking (no, yes), alcohol consumption (no, yes), frequency of alcohol consumption (<1/month, 1/month, 2-4/month, 2-3/week, ≥4/week), amount of alcohol consumption (1-2 cups, 3-4 cups, 5-6 cups, 7-9 cups, over 10 cups), and sleep duration (lack, normal, over). For sleep duration, participants were divided into the following three groups: 1) lack of sleep (<6 h), 2) normal sleep (6 to <10 h), and 3) over sleep (≥10 h)(Centers for Disease Control and Prevention (CDC), 2018; Jeong & Kim, 2019; Kim & Lee, 2019).

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Physical health condition

The variables of physical health condition included oral health (good, average, bad), stress (much, little), depression (no, yes), suicidal thinking (no, yes), suicide attempt (no, yes), hypertension (no, yes), diabetes (no, yes), falls (no, yes), accident or addiction (no, yes), and Body Mass Index (BMI, kg/m2) (underweight [<18.5], normal [18.5 to <23], overweight [23 to <25], obesity [≥25]).

Statistical analysis

Data analysis was performed using SPSS (version 29.0; IBM Corp., Armonk, NY, USA). Chi-square and independent t-tests were used to compare the characteristics of the participants. Decision tree analysis was used to build a prediction model for cognitive dysfunction in the older population. Decision tree analysis is a useful method for establishing a prediction model by splitting big data into smaller groups (Choi & Seo, 1999). This study used the chi-square automatic interaction detection method to manage both continuous and categorical variables (Seo & Kim, 2021). For the analysis, sleep duration was designated as the first branch. In addition, the maximum tree depth was set to three, and the minimum number of cases for parent and child nodes was 100 and 50, respectively (Choi & Seo, 2016; Seo & Kim, 2019).

A split-sample test was performed to examine the validity of the final decision tree. To perform the validation test, the total number of participants was divided into training and test data (Choi et al., 1998). The generalizability of the prediction model produced by the training data was compared with that generated by the test data (Choi & Seo, 1999). If there was no significant difference in risk estimates between the two models, generalization was assumed (Choi et al., 1998).

In this study, multiple logistic regression was performed to identify the relationship between cognitive dysfunction and factors, including general characteristics, socioeconomic characteristics, health behaviors, and physical health conditions. Statistical significance was set at p≤.05.

Ethical statement

This study used the public data provided by the Korea Disease Control and Prevention Agency. An Institutional Review Board (IRB) exemption was obtained from the author's university (IRB no. 10411495-202304-HR-01-01).

RESULT

Characteristics of participants

In this study, two groups were formed based on cognitive dysfunction. Individuals with and without experience of cognitive dysfunction were included in the yes and no groups, respectively. In total, the yes and no groups included 2,426 (72.2%) and 935 (27.8%) individuals, respectively. The two groups showed statistically significant differences in age (p<.001), subjective health status (p<0.001), economic activity (p=0.002), sleep duration (p=0.027), oral health (p=0.002), stress (p=0.010), depression (p=0.002), suicidal thinking (p=0.040), and falls (p=0.001) (Table 1).

Regarding general characteristics, most of the participants in the two groups were in the age group of 75-84 years (p<0.001). Participants in the yes group showed a higher rate (81.0%) of bad health status than those in the no group (72.8%) (p<0.001). There were no significant differences in sex (p=0.341), location (p=1.000), life satisfaction (p=0.123), or marital status (p=0.316) between the two groups.

Regarding economic activity, participants in the yes group showed a higher rate of 'no' (82.8%) than the participants in the no group (p=0.002). There was no difference in education level (p=0.252) and basic livelihood recipients (p=0.291) between the two groups.

Regarding the characteristics of health behaviors, there was a significant difference in sleep duration. Participants in the yes group showed a higher rate of oversleeping (5.7%) than those in the no group (3.4%) (p=0.027). However, the rates of lack of sleep and normal sleep were lower in the yes group than in the no group. There were no differences in the frequency of breakfast consumption (p=0.124), smoking (p=0.369), alcohol consumption (p=0.787), frequency of alcohol consumption (p=0.356), or amount of alcohol consumption (p=0.442) between the two groups.

Participants in the yes group showed a higher rate (78.2%) of bad oral health than those in the no group (72.6%) (p=0.002). The percentage of participants who felt much stressed was higher in the yes group (58.8%) than in the no group (53.8%) (p=0.010). Additionally, participants in the yes group (48.4%) showed a higher rate of depression than those in the no group (42.4%). Participants in the yes group had higher rates of suicidal thoughts (55.9%) than those in the no group (52.0%) (p=0.040). The rate of falls in the yes group (38.2%) was higher than that in the no group (32.2%) (p=0.001). However, there were no differences in suicide attempts (p=0.067), hypertension (p=0.077), diabetes (p=0.583), accidents or addiction (p=0.279), or BMI (p=0.296).

Table 1. Characteristics of Subjects (N=3,361)

Characteristics	Cognitive dysfunction				p-value
	Yes group (n=2,426, 72.2%)		No group (n=935, 27.8%)		
	Frequency	Percentage	Frequency	Percentage	
General characteristics					
Age					<.001
65-74	84	34.8	394	42.1	
75-84	1096	45.2	407	43.5	
Over 85	485	20.0	134	14.3	
Sex					0.341
Male	647	26.7	265	28.3	
Female	1779	73.3	670	71.7	
Location					1.000
Province	1776	73.2	685	73.3	
City	650	26.8	250	26.7	
Subjective health status					<0.001
Bad	1966	81.0	681	72.8	
Average	360	14.8	195	20.9	
Good	100	4.1	59	6.3	
Life satisfaction					0.123
Low	1747	72.4	647	69.6	
High	666	27.6	282	30.4	
Marital status					0.316
Single	1302	53.7	484	51.8	
Married	1123	46.3	451	48.2	
Socio-economic characteristics					
Education level					0.252
≤High school	2328	96.0	888	95.1	
≥College school	97	4.0	46	4.9	
Basic livelihood recipient					0.291
No	1982	81.7	784	83.9	
Yes	443	18.3	151	16.1	
Economic activity					0.002
No	2008	82.8	730	78.1	
Yes	418	17.8	205	21.9	
Health behaviors					
Frequency of breakfast					0.124
3-4/week	290	67.6	77	38.9	
5-7/week	139	32.4	121	61.1	
Smoking					0.369
No	409	67.8	151	64.5	
Yes	194	32.2	83	35.5	
Drinking					0.787
No	1128	46.5	440	47.1	
Yes	1296	53.5	495	52.9	
Frequency of drinking					0.356
None	887	68.4	314	63.4	
<1/month	131	10.1	64	12.9	
1/month	59	4.6	26	5.3	
2-4/month	85	6.6	33	6.7	
2-3/week	63	4.9	24	4.8	
≥4/week	71	5.5	34	6.9	

Characteristics	Cognitive dysfunction: Yes group (n=2,426, 72.2%)		Cognitive dysfunction: No group (n=935, 27.8%)		p-value
	Frequency	Percentage	Frequency	Percentage	
Amount of drinking					0.442
1-2cups	243	59.4	101	55.8	
3-4cups	89	21.8	34	18.8	
5-6cups	20	4.9	13	7.2	
7-9cups	37	9.0	23	12.7	
Over 10 cups	20	4.9	10	5.5	
Sleep time					0.027
Lack	1195	49.3	47	50.5	
Normal	1093	45.1	43	46.1	
Over	138	5.7	32	3.4	
Physical health condition					
Oral health					0.002
Good	511	21.1	249	26.6	
Average	18	0.7	7	0.7	
Bad	1897	78.2	679	72.6	
Stress					0.010
Little	999	41.2	432	46.2	
Much	1423	58.8	503	53.8	
Depression					0.002
No	1251	51.6	539	57.6	
Yes	1173	48.4	396	42.4	
Suicidal thinking					0.040
No	1069	44.1	449	48.0	
Yes	1357	55.9	486	52.0	
Suicidal attempt					0.067
No	2356	97.1	919	98.3	
Yes	70	2.9	16	1.7	
Hypertension					0.077
No	997	41.1	353	37.8	
Yes	1429	58.9	582	62.2	
Diabetes					0.583
No	1720	70.9	654	69.9	
Yes	706	29.1	281	30.1	
Fall down					0.001
No	1499	61.8	634	67.8	
Yes	927	38.2	301	32.2	
Accident or addiction					0.279
No	2135	88.0	836	89.4	
Yes	291	12.0	99	10.6	
Body Mass Index					0.296
Underweight	266	11.0	87	9.2	
Normal	1054	43.4	398	42.6	
Overweight	422	17.4	183	19.6	
Obesity	684	28.2	267	28.6	

Prediction model for the experience of cognitive dysfunction in older individuals

To identify the experience of cognitive dysfunction according to sleep duration, after fixing sleep duration as the first separation criterion, a decision tree analysis including all factors was performed. The final prediction model comprised eight nodes (Figure 1). Sleep duration was a significant factor affecting the experience of cognitive dysfunction (F=7.216, p=0.022). We found that 71.7% of the participants in the lack of sleep and normal sleep groups and 81.2% of the participants in the over sleep group experienced cognitive dysfunction.

In the case of the lack of sleep and normal sleep groups (Node 1), there was a difference in cognitive dysfunction experience according to age (F=17.489, p<0.001). The 75-84 age group (Node 2) showed a significant difference in cognitive dysfunction experienced by depression (F=9.588, p=0.006). Cognitive dysfunction was observed in 76.6% and 69.3% of the participants with and without depression, respectively. Those aged 65-74 years showed significant differences in cognitive dysfunction according to their stress levels. Participants who felt little and much stress experienced cognitive dysfunction at the rates of 63.0% and 70.5%, respectively. For participants aged ≥85 years, BMI was a significant factor related to the experience of cognitive dysfunction (F=7.538, p=0.042). Approximately 80.1% of the participants who were normal, overweight, or underweight experienced cognitive dysfunction. In addition, 69.0% of participants with obesity experienced cognitive dysfunction.

For the over sleep group, the experience of cognitive dysfunction differed according to depression (F=4.468, p=0.035). A total of 76.2% of the participants with depression and 89.2% of those without depression experienced cognitive dysfunction.

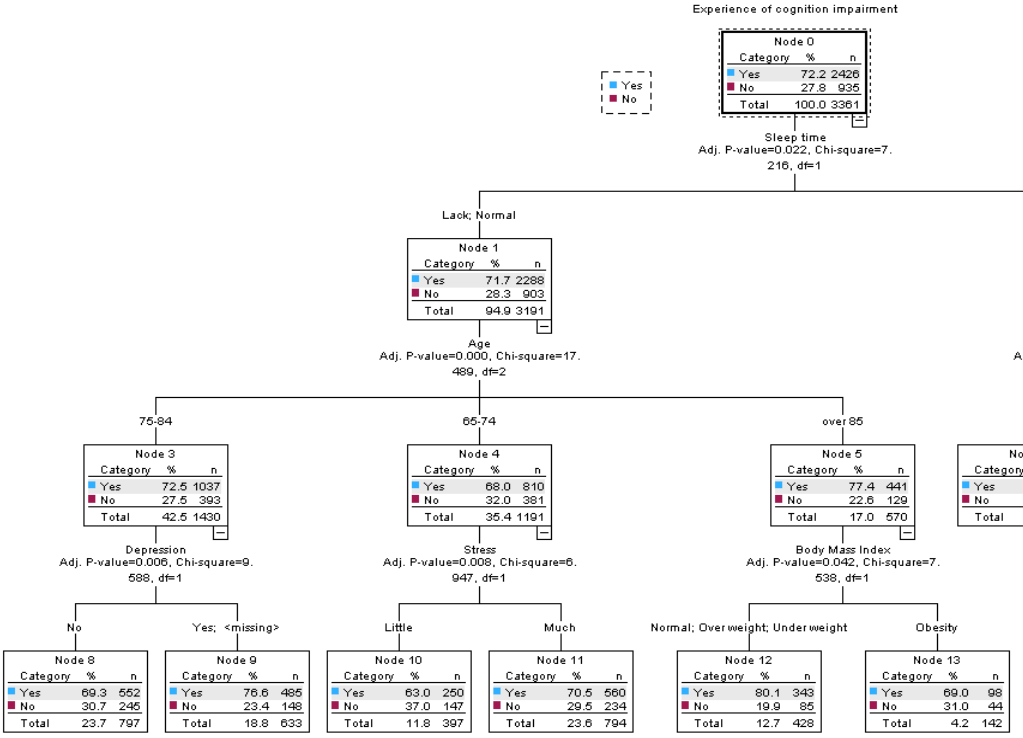

Figure 1. Prediction model for cognitive dysfunction of elderly

Validation of the prediction model for the experience of cognitive dysfunction

The results of the validation test for the prediction model are presented in Table 2. For the training data, the risk estimate was 0.29, indicating that the probability of accurate classification was 71%.

Table 2. Risk chart of decision trees

Variables	Risk estimate	SE
Training data	0.29	0.01
Test data	0.27	0.01

Factors influencing the experience of cognitive dysfunction in older individuals

Logistic analysis showed that the regression model was significant (χ^2=74.38, p<0.001) (Table 3). The six factors that predicted cognitive dysfunction were sleep duration, age, health status, stress level, depression, and falls. Compared with the normal sleep group, the over sleep group was 1.63 times more likely to experience cognitive dysfunction (p=0.017, 95% confidence interval [CI]=1.09-2.45). In addition, compared with the 65-74 years group, the 75-84 years group was 1.25 times (p=0.010, 95% CI=1.06-1.48) and the ≥85 years group was 1.38 times (p<0.001, 95% CI=1.39-2.23) more likely to experience cognitive dysfunction. Participants with bad health status were 1.38 times more likely to experience cognitive dysfunction than those with average/good health status (p=0.002, 95% CI=1.13-1.68). Participants with a lot of

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stress were 1.20 times more likely to experience cognitive dysfunction than those with less stress (p=0.031, 95% CI=.02-1.41). Those who had depression or experienced a fall were 1.29 times (p=0.002, 95% CI=1.10-1.51) and 1.21 times (p=0.021, 95% CI=1.03, 1.43) more likely to experience cognitive dysfunction than those without depression or fall.

Table 3. Factors affecting experience of cognitive dysfunction in elderly

Variables	B	SE	Sig	Exp(B)	95% Confidence Interval	
					Lower	Upper
Constant	0.401	0.125	<0.001	1.493		
Sleep time (lack) (ref.=Normal)	-0.022	0.080	0.785	0.979	0.837	1.144
Sleep time (Over) (ref.=Normal)	0.491	0.206	0.017	1.634	1.090	2.448
Age (75-84) (ref.=65-74)	0.225	0.087	0.010	1.252	1.056	1.484
Age (Over 85) (ref.=65-74)	0.566	0.120	<0.001	1.761	1.392	2.227
Subject health status (Bad) (ref.=Average)	0.319	0.102	0.002	1.376	1.126	1.681
Subject health status (Good) (ref.= Average)	-0.138	0.188	0.464	0.871	0.602	1.260
Stress (Much) (ref.=Little)	0.178	0.083	0.031	1.195	1.016	1.406
Depression (Yes) (ref.=No)	0.253	0.082	0.002	1.288	1.096	1.513
Fall down (Yes) (ref.=No)	0.191	0.083	0.021	1.211	1.029	1.425

DISCUSSION

Cognitive dysfunction in older adults is a serious health concern worldwide (Bademli et al., 2018). Older individuals who experience cognitive dysfunction have been found to develop dementia (Faubel et al., 2009). Dementia is a chronic disease that is difficult to treat and is progressive (Honghao et al., 2020). Therefore, it is necessary to identify factors that affect cognitive dysfunction (Faubel et al., 2009). Thus, this study aimed to build a model to predict the experience of cognitive impairment in older adults, with a particular focus on sleep duration.

The results of this study showed that those who slept for ≥10 h and had depression experienced the highest rate (89.2%) of cognitive dysfunction. In contrast, people aged 65-74 years with low or average sleep duration and low stress levels were the least likely to experience cognitive dysfunction (63.0%). In line with these results, another study found that the decrease in cognitive function among those who slept for >11 h was similar to that associated with a 10-year increase in age (Durmer & Dinges, 2005). In addition, a study reported that long sleep duration was related to worse cognitive dysfunction, while there was no association between short sleep duration and cognitive dysfunction (Faubel et al., 2009). Some research results contradict those of the present study. A previous study found that lack of sleep is significantly related to a low level of cognitive function (Durmer & Dinges, 2005). Moreover, no association was found between short sleep duration (<7 h) and levels of cognitive function (Durmer & Dinges, 2005). A previous study found that both sleep deprivation and oversleeping were related to cognitive dysfunction; however, the study did not include older adults (Kronholm et al., 2009). In contrast, a study showed that lack of sleep or oversleeping are not associated with cognitive dysfunction (Devore et al., 2012). Thus, the relationship between cognitive dysfunction and sleep duration appears to be inconsistent across studies. In addition, the definition of the standard for appropriate sleep duration varies in previous studies. Since studies on the relationship between sleep duration and cognitive dysfunction in older individuals are rare, further studies identifying the relationship between sleep duration and cognitive dysfunction with a clear definition of appropriate sleep duration should be conducted.

Regarding the relationship between sleep, depression, and cognitive function, Wu et al. (2019) found that difficulty in initiating sleep mediated the relationship between depression and cognitive dysfunction in older men; moreover, depression was significantly related to cognitive dysfunction in older men (Wu et al., 2019). Guan et al. (2020) reported that sleep disturbances mediated the association between depression and cognitive function. However, it is difficult to compare the results of this study with those of the previous study because no sleep duration was specified in either study. In addition, there was a contradicted results that there was no relationship between depression and cognitive impairment in Korean elderly (Shin et al.,2012). Therefore, it is necessary to examine the relationship between depression and cognitive function in elderly in further studies.

In this study, relatively young older adults who were less stressed and had below-average sleep duration were the least likely to suffer from cognitive impairment. Similar to the results of this study, it has been shown that cognitive dysfunction tends to worsen with age (Gildner et al., 2014; Murman, 2015). Based on our findings, it can be assumed that if stress is low, despite the sleep duration being short, the quality of sleep is high, and the possibility of cognitive dysfunction is low.

It is crucial to identify people at high risk of cognitive dysfunction because early identification of cognitive dysfunction plays a pivotal role in preventing the development of dementia (Hua et al., 2020; Jo, 2009). Because dementia affects the quality of life and imposes a global health burden, preventing the progression from cognitive dysfunction to dementia is necessary. However, few studies have investigated the effects of sleep duration on cognitive function in the older population. In addition, few studies have been conducted to identify high-risk groups for cognitive dysfunction in older adults, considering various factors, including sleep time. Thus, this study has great significance since it built a model to identify high-risk groups with cognitive impairment, considering sleep duration in older adults.

Despite these strengths, this study had several limitations. First, the variables, including the experience of cognitive dysfunction and sleep duration, were self-reported data with the possibility of recall bias. In addition, cognitive function may affect an individual's perception of sleep duration. Second, variables that were significant in previous studies, such as marital status, sex, and educational level, were not included in the final model. Third, this study did not include all the factors related to cognitive dysfunction in older adults. Fourth, the rate of imbalance between the two groups (yes or no) may have influenced the results. Fifth, the definition of normal sleep duration in this study was >6 h and <10 h. However, it is difficult to generalize the results of this study because the standards for appropriate sleep duration for older individuals are diverse. Finally, sleep quality may be an important factor affecting cognitive function and sleep duration, and it should be considered in future studies.

CONCLUSION

This study found that oversleeping in older adults was significantly related to the experience of cognitive dysfunction. Specifically, those aged $\geq$65 years, those sleeping $\geq$10 h a day, and those with depression showed the highest rates of cognitive dysfunction. Subjects who are older, sleep longer, and are depressed are more likely to experience cognitive dysfunction. Therefore, it is necessary to consider age, sleep duration, and depression when developing programs aimed at preventing and managing cognitive dysfunction. Furthermore, regular monitoring should be conducted to detect any occurrence of cognitive dysfunction in the elderly. Further studies are needed to identify other factors related to cognitive dysfunction.

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