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Original Article

Cognitive Function and Its Risk Factors in a National Survey of Older Adults in Taiwan: A Latent Class Analysis

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A R T I C L E I N F O

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S U M M A R Y

Background: This study aimed to categorize older adults into subgroups according to their health behaviors and compare the risk of cognitive impairment of these groups.
Methods: Cross-sectional data were from the 2013 National Health Interview Survey in Taiwan. A total of 2,817 older adults were analyzed using the latent class analysis (LCA) method to categorize their health behaviors. Logistic regression was used to identify the potential risks and protective factors of cognitive impairment.
Results: Latent class analysis (LCA) identified six classes. The results of logistic regression showed that the physically and socially inactive group faced a 68% higher risk of cognitive impairment (odds ratio, 1.68; 95% confidence interval, 1.20–2.35) and the physically and socially active group faced a 68% lower risk of cognitive impairment (odds ratio, 0.32; 95% confidence interval, 0.19–0.55) than the reference (sound-health-status) group.
Conclusions: The findings offer insights and implications that are useful for the future planning of related interventions to reduce the risk and incidence of cognitive impairment.

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1. Introduction

Cognitive decline and one of its most serious consequences, dementia, are priority healthcare concerns worldwide.[1] According to Alzheimer's Disease International (2015), approximately 46.8 million people worldwide currently live with dementia. Moreover, this figure is continuing to increase rapidly, with the number of dementia sufferers worldwide projected to reach 74.7 million by 2030.[2] An epidemiological study in Taiwan estimated a domestic population of 190,000 people with dementia in 2011, with this number expected to reach 720,000 people in 2050.[3] A nationwide survey in Taiwan found a prevalence rate of dementia of 8.04% and a prevalence rate of mild cognitive impairment of 18.76%.[4] Dementia has become a main cause of disability and also admissions to long-term care placements due to disability to perform activities of daily living.[5] Therefore, identifying the risk factors that relate to cognitive decline can aid in reducing the incidence of cognitive impairment and dementia.

Previous studies have identified a wide variety of risk factors related to dementia and cognitive impairment. These factors may be grouped into several categories, including demographics (e.g., age, gender, education, marital status, living arrangement, body mass index, obesity),[6–8] health-related factors (e.g., chronic illness, depressive mood, vision, hearing loss),[9–11] and health behaviors (e.g., smoking, alcohol consumption,[12,13] exercise,[14–16] sedentary lifestyle,[17] and social engagement).[18,19] As the primary focus of this paper is on health-related factors, the following review addresses the research related to these factors.

Based on a review of current studies, health behaviors may be present either as risk factors or protective factors. For instance, smoking and excessive alcohol consumption have been identified as risk factors for cognitive impairment.[12,13] While Sinforiani et al. (2011) identified that mild to moderate alcohol consumption as a potentially protective factor against cognitive decline, the findings of other studies were less consistent.[20] In addition, many studies have identified physical activities such as exercise, walking, and biking as significant protective factors against cognitive decline,[14–16] while leading a sedentary lifestyle has been shown to have a significantly negative effect on cognitive function, especially in older adults who sit for more than five hours a day.[17] Some studies show that disturbed sleep is a predictor of dementia. Moreover, longer sleep duration has been associated with cognitive decline, with older adults who sleep more than seven hours a day having poorer cognitive function than those sleep less than seven hours a day.[22] Furthermore, participation in social and leisure activities has been found to reduce the risks of cognitive impairment and dementia in older adults, while lack of participation in social activities has been identified as a risk factor of cognitive decline.[18,19,23]

Although health behaviors have been identified as predictors of cognitive impairment and dementia, these behaviors have largely been treated as individual predictors and not as composite acts. Therefore, this study was designed to improve current knowledge by clustering relevant behaviors together using the latent class analysis (LCA) method to analyze the potential classes and characteristics of

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study groups to identify the corresponding independent attributes of each class.

The purpose of this study was threefold: 1) to categorize older adults into subgroups according to 14-item health behaviors, 2) to describe the characteristics of each group and, 3) to compare the risk of cognitive impairment in these groups while adjusting for potential confounders.

2. Materials and methods

2.1. Data source

This cross-sectional study extracted data for analysis retrospectively from the 2013 National Health Interview Survey (NHIS), a database set up by the Health Promotion Administration, Ministry of Health and Welfare and National Health Research Institutes (NHRI). A group of interviewers was recruited and trained to collect data via face-to-face interviews at participants' homes using a structured questionnaire that included demographic characteristics, health status, health behaviors, and two standardized instruments, including a short form of the Center for the Epidemiological Studies of Depression (CES-D) and Mini-Mental State Examination (MMSE). A multidisciplinary team at the NHRI validated and approved the questionnaire to ensure reliability and validity prior to the interviews. The Institutional Review Board of the institute approved the present analysis (EC1050702-E) by waiving the requirement of informed consent from the participants due to the retrospective design and the anonymized nature of participant information in the database.

2.2. Study sample

A nationally representative sample of 30,960 individuals, including 3,868 people aged 65 years or older, was selected using the sampling method of Probability Proportional to Size from a household statistics registry provided by the Department of Household and Registration, Ministry of the Interior in Taiwan on December 31st, 2012. This sample excluded individuals who were currently living abroad or residing in military units, hospitals, or prisons. Computer Assisted Personal Interviewing and face-to-face interviews were conducted between July 2013 and December 2013. A total of 23,273 individuals (75.2%) completed the interview, including 3,203 adults aged 65 years or older (82.8%). Of the 3,203 older adults, 22 were excluded due to missing values in other variables and 364 were excluded from collecting data on CES-D and MMSE. Thus, a total of 2,817 older adults were included in this analysis (Figure 1).

2.3. Variables

Socio-demographic data collected from participants included gender, age, education level, marital status, living arrangement, and residential area.

Health status included the variables of depressive mood, hearing, vision, and chronic diseases. Participants were asked to report diagnosed diseases, including diabetes, stroke, asthma, renal disease, heart disease, gastrointestinal disease, respiratory disease, liver disease, arthritis, dementia, and cancer. The present study used the Charlson Comorbidity Index (CCI) to assess disease severity.[24] On the CCI, a score of one, two, three, or six is assigned to each of the 19 diagnosed illnesses, with higher scores indicating greater severity. A short form of the CES-D that consisted of 10 items was used to assess depressive mood. The scores for each item were summed (possible range: 0–30), with higher scores indicating a more-severe depressive mood. The scores were separated into two subgroups: no depressive mood ($\leq$ 10) and depressive mood (> 10).[25]

Health behaviors included 14 items addressing physical and social activities, sleeping patterns, smoking, alcohol consumption, and body mass index (underweight is BMI $\leq$ 18.5, normal is 18.5 $\leq$ BMI < 24, overweight is 24 $\leq$ BMI < 27, obese is BMI $\geq$ 27).[26] The physical activity items included vigorous labor such as farming or building; walking or biking; exercise such as yoga, aerobic dance, or using exercise machines at least 10 minutes during the past month. In addition, participants were asked whether they had engaged in face-to-face social interaction with family members, friends, or neighbors during the past three months. Sedentary lifestyle was assessed by whether participants carried out daily activities such as watching TV, reading, using the computer, playing video games, or doing office work while seated for five hours or more per day.[17] Sleeping patterns included sleeping duration, afternoon napping habit, snoring, and apnea.

Cognitive function was assessed using the MMSE.[27] Cutoff scores for determining impairment were adjusted according to education level. A cutoff score of 16 was used for participants with an informal education, 21 was used for those with an elementary school education, and 24 was used for those with a middle school or higher education level.[3] According to the cutoff score of MMSE, cognitive function was identified as two subgroups: impaired and normal.

2.4. Statistical analysis

Statistics Analysis System 9.3 (SAS) software was used for three types of data analysis. Each health behavior variable was classified into two to four categories. Latent class analysis was used to cluster 14-item health behaviors based on person-centered and to generate five models, each of which included two to six classes. The model goodness of fit between latent classes and corresponding items was determined on the basis of a number of indicators, including Log-likelihood, G-squared, Akaike's Information Criterion (AIC), Bayesian Information Criterion (BIC), Consistent Akaike's Information Criterion (CAIC), and entropy. According to these indicators, six classes were identified. In addition, chi-square tests were conducted to examine the relationship between the categorized classes and socio-demographic characteristics, health status, and cognitive function. Finally, logistic regression was used to explore the risk of cognitive decline in each class and to compare them to the reference group after adjusting for gender, age, education level, marital status, living

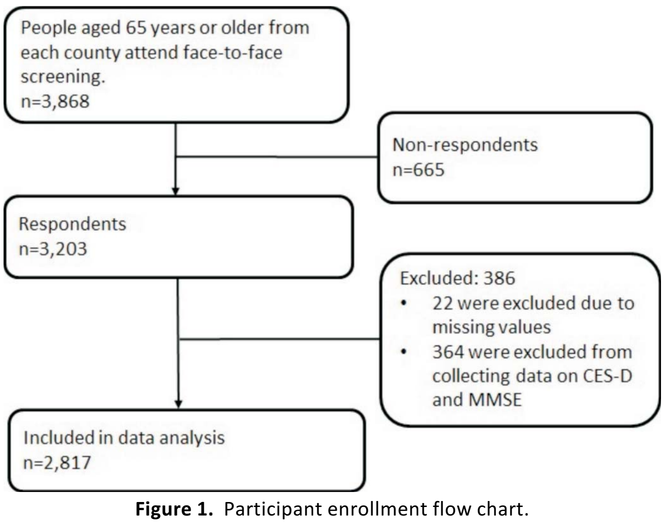

Figure 1. Participant enrollment flow chart.

arrangement, residential area, depressive mood, hearing loss, vision, and CCI as potential confounders.

3. Results

Table 1 presents demographic characteristics. The majority of participants in this study were female (52.6%) and aged 65 to 74 (57.3%), approximately 44.6% were educated to an elementary school level, most were married (63.8%) and were living with others (88%). Slightly over half (52.9%) lived in township or rural areas. Table 1 also presents the results for health status. The mean participant score for the weighted comorbidity index was 1.06 (SD = ±1.31), representing a mild condition. Approximately 43.9% had no chronic diseases (CCI score = 0). Of the 2,817 participants, 305 (10.8%) had depressive mood and 2,333 (82.8%) had visual impairment. The majority were free from hearing loss (85.4%) and cognitive impairment (86.5%).

Table 2 presents model fit statistics of latent class analysis. Five models were generated, with two to six classes, respectively, in each. A comparison of goodness-of-fit statistics showed that the model with six classes had the optimal fit, given that four of its fit indexes, particularly AIC, the most important indicator, were the lowest of all models. Although the model with four classes exhibited good fit, given that BIC and CAIC earned the lowest fitness indexes of all models, the model with six classes was ultimately chosen due to its optimal fit and the heterogeneity between health behaviors and characteristics in elderly people, which requires a larger number of classes to explicate.

Table 3 presents the distributions for each group, including class 1 (n = 490, 17.4%), 2 (n = 201, 7.1%), 3 (n = 336, 11.9%), 4 (n = 713, 25.3%), 5 (n = 691, 24.5%), and 6 (n = 386, 13.7%). Table 3 also shows the probabilities of 14-item health behaviors presented in each group. Clustering certain behaviors helps characterize a group and suggest an appropriate label. For example, smoking and alcohol consumption had a higher probability in class 1 than in other classes. Other results included vigorous labor for class 2, sedentary lifestyle and lower social engagement for class 3, obesity and sleep disturbance (snoring and sleep apnea) for class 4, and physically and socially active for class 6. Class 5 was selected as the reference group, with its sound composite of low smoking and alcohol consumption, moderate physical activity and social engagement, and good sleeping quality.

Table 4 presents the results of multivariate logistic regression analysis on cognitive function, as represented by MMSE score. These results indicate that, after adjusting for confounding factors, class 3 (odds ratio [OR] = 1.68, 95% confidence interval [CI] 1.20–2.35) was more likely to be cognitively impaired and class 4 (OR = 0.71, 95% CI 0.52–0.98) and class 6 (OR = 0.32, 95% CI 0.19–0.55) were less likely to be cognitively impaired than class 5. In addition, each of the following was significantly associated with being at a higher risk of cognitive impairment: aged 75 to 84 (OR = 2.09, 95% CI 1.62–2.70), aged 85 or older (OR = 3.11, 95% CI 2.09–4.61; with 65 to 74 years of age used as the reference group), being educated to an elementary school level (OR = 1.39, 95% CI 1.02–1.89; as compared to the middle school and above group), depressive mood (OR = 2.29, 95% CI 1.69–3.10), hearing loss (OR = 1.50, 95% CI 1.12–2.01), CCI score of 1 (OR = 1.29, 95% CI 0.97–1.71), and CCI score of 2 or higher (OR = 1.41, 95% CI 1.06–1.86).

4. Discussion

The rate of participants with cognitive impairment in this na-

Table 1
Distribution of demographic characteristics and health status (n = 2,817)

Variables	n (%)	Mean (SD)
Gender		
Male	1336 (47.4)	
Female	1481 (52.6)	
Age		74.54 (6.52)
65–74	1614 (57.3)	
75–84	992 (35.2)	
≥ 85	211 (7.5)	
Education level		
Informal education	820 (29.1)	
Elementary school	1257 (44.6)	
Middle school and above	740 (26.3)	
Marital status		
Married	1798 (63.8)	
Separated, divorced, widowed, never married	1019 (36.2)	
Living arrangement		
Not living alone	2480 (88.0)	
Living alone	337 (12.0)	
Residential area		
Urban	732 (26.0)	
Suburban	595 (21.1)	
Township	606 (21.5)	
Rural	884 (31.4)	
Depressive mood		4.48 (4.66)
No	2512 (89.2)	
Yes	305 (10.8)	
Hearing		
Normal	2405 (85.4)	
Loss	410 (14.6)	
Vision		
Normal	483 (17.2)	
Impairment	2333 (82.8)	
Comorbidity index		1.06 (1.31)
Score 0	1236 (43.9)	
Score 1	789 (28.0)	
≥ Score 2	792 (28.1)	
Cognitive function		24.01 (4.93)
Normal	2438 (86.5)	
Impairment	379 (13.5)	

Table 2
Model fit statistics of latent class analysis on fourteen health behavior variables.

Number of latent classes	Log-likelihood	G-squared	AIC[a]	BIC[b]	CAIC[c]	Adjusted BIC	Entropy	Degrees of freedom
2	-23514.53	7127.40	7197.40	7403.82	7405.42	7294.21	0.74	49116
3	-23368.42	6835.18	6941.18	7256.18	7309.18	7087.78	0.55	49098
4	-23273.38	6645.10	6787.10	**7209.08**	**7280.08**	6983.49	0.58	49080
5	-23217.19	6532.71	6710.71	7239.68	7328.68	6956.90	0.60	49062
6[d]	-23155.70	6409.73	**6623.73**	7259.68	7366.68	6919.70	0.63	49044

Note: [a] AIC = Akaike's Information Criterion. [b] BIC = Bayesian Information Criterion. [c] CAIC = Consistent Akaikes Information Criterion. [d] Best fitting across the six classes. Model fit statistics: lower values of AIC indicate better fit.

Table 3
Probabilities of latent classes for health behaviors (n = 2,817).

Variable	Class 1 n (%)	Class 2 n (%)	Class 3 n (%)	Class 4 n (%)	Class 5[a] n (%)	Class 6 n (%)
Total	490 (17.4)	201 (7.1)	336 (11.9)	713 (25.3)	691 (24.5)	386 (13.7)
Smoking						
Current	**0.2879**	0.2692	0.0646	0.0572	0.0740	0.0465
Quit	**0.5986**	0.0713	0.0990	0.0624	0.0538	0.0795
Alcohol consumption	**0.9919**	0.3241	0.1270	0.2072	0.1255	0.4322
Physical activities						
Vigorous labor	0.1905	**0.9818**	**0.0435**	0.1296	0.1086	0.3348
Walking or biking	0.2952	0.3411	**0.1740**	0.2719	0.2862	**0.5565**
Exercise	0.5905	0.1069	**0.2868**	0.4710	0.5053	**0.9659**
Sedentary lifestyle (> 5 hours a day)	0.4634	0.0674	**0.5457**	0.5837	0.4016	0.2258
BMI						
Underweight	0.0143	0.0463	0.0955	0.0318	0.0498	0.0049
Normal	0.4670	0.4592	0.5034	0.3446	0.5378	0.5585
Overweight	0.3348	0.3263	0.2636	**0.2888**	0.2374	0.3541
Obesity	0.1839	0.1683	0.1375	**0.3347**	0.1750	0.0825
Sleeping pattern						
Duration (> 7 hours a day)	0.1909	0.1427	0.2156	0.1820	0.2312	0.0875
Afternoon napping habit	0.7022	0.5388	0.7015	0.7187	0.5963	0.7529
Snoring	0.5909	0.3910	0.3803	**0.9074**	0.0470	0.5605
Apnea	0.0860	0.1202	0.0804	**0.2571**	0.0009	0.0222
Social engagement						
With family members	0.9305	0.9712	**0.8701**	0.9356	0.9632	**0.9685**
With friends	0.6729	0.6296	**0.0997**	0.6299	0.5558	**0.8952**
With neighbors	0.6168	0.7903	**0.1764**	0.7767	0.9003	0.7662

Note: [a] Reference group.

tionally representative sample was 13.5%. Analyzing data retrospectively from the NHIS in Taiwan, six health-behavior groups were identified using the latent class analysis method. These groups included: smoking and alcohol consumption (class 1), vigorous physical labor (class 2), physically and socially inactive (class 3), obesity and sleep disturbance (class 4), sound composite health status with good sleep quality (class 5 as reference group), and socially and physically active (class 6). Although fewer clusters would have reduced the issue of overlapping characteristics among the groups, a six-group approach was chosen due to both the optimal goodness of fit index and the wide diversity among the elderly population in the sample. A major concern of clustering relates to distinctiveness or exclusiveness. This was less of a problem in our study because each group was generalized by clustering specific health behaviors with similar characteristics. For example, while classes 2 and 6 seem similar, examining the prominent items of health behaviors that are loaded on each group clearly reveals the differences between the two, with class 6 being both socially active and physically active while class 2 being vigorous physical labor.

The results of logistic regression indicate that, in comparison with the sound-health-status group (reference group), the physically and socially inactive group (class 3) faced a 68% higher risk and the physically and socially active group (class 6) faced a 68% lower risk of cognitive impairment. This result points to the inadequacies in class 5 participants, who merely maintained their sound health status and good sleep quality, and reaffirms the importance of remaining physically and socially active to reduce the risk of cognitive impairment, as documented in previous studies. For example, several studies have associated physical activities such as exercise, walking, and biking with a reduction in the risk of cognitive impairment, including both mild cognitive impairment (MCI) and dementia.[14–16] Previous studies have also demonstrated that aggressive engagement in social or leisure activities and a rich social network in late-life are conducive to decreasing the risk of developing dementia.[18,19,23]

Another finding from multivariate logistic regression analysis showed that the group with problems of obesity and disturbed sleep (class 4) faced a 29% lower risk of cognitive impairment compared to the reference group (class 5). This result seems counterintuitive, as being obese and experiencing sleep disturbance are both recognized risk factors of cognitive impairment. A review of the literature reveals inconsistent findings regarding the relationship between BMI and cognitive impairment. While some studies have reported the lack of a significant correlation,[6,7] those that have documented a significant relationship found conflicting results in terms of the direction of the correlation, with some reporting a positive correlation between being overweight / obese and risk of cognitive impairment[28,29] and others reporting an opposite result.[8] Consequently, the findings from this and previous studies should be interpreted as inclusive.

The results of previous studies related to the impact of sleep disturbance are more consistent. Most have reported that elderly people with sleep disturbance are more likely to be cognitively impaired than their peers.[21] Thus, the grouping of BMI and sleep quality together into one cluster in this study complicates this issue, making it difficult to determine whether snoring and sleep apnea alone or in combination with BMI were responsible for cognitive impairment. One possible explanation lies in the length of time that an individual was affected by this “double jeopardy” situation. For example, one study reported that being obese affected cognitive impairment only when an individual had this problem from middle age to old age.[30] Information regarding the duration of this double-jeopardy situation was not available in the data used for this study. An examination of other health behaviors from the LCA results indicates that the participants from the two groups under comparison also had high probabilities of engaging in three types of social activities. The probability of making contacts with friends was higher in class 4 and the probabilities of engaging, respectively, with family and neighbors were higher in class 5. Thus, it is difficult to determine which type of social activity was more important in lessening the risk

Table 4
Multivariate logistic regression analysis on cognitive function.

Variable	Unadjusted		p value	Adjusted[a]		p value
	OR	95% CI		OR	95% CI	
Latent classes						
Class 1	0.67	(0.47–0.95)	0.019*	0.74	(0.50–1.10)	0.140
Class 2	0.52	(0.31–0.88)	0.012*	0.68	(0.39–1.17)	0.160
Class 3	2.11	(1.55–2.88)	< 0.001***	1.68	(1.20–2.35)	< 0.001***
Class 4	0.70	(0.51–0.95)	0.021*	0.71	(0.52–0.98)	0.041*
Class 5	1			1		
Class 6	0.24	(0.14–0.41)	< 0.001***	0.32	(0.19–0.55)	< 0.001***
Demogrpahic characteristics						
Gender						
Male	1			1		
Female	1.18	(0.95–1.47)	0.129	1.19	(0.89–1.59)	0.240
Age						
65–74	1			1		
75–84	2.56	(2.02–3.25)	< 0.001***	2.09	(1.62–2.70)	< 0.001***
≥ 85	3.96	(2.78–5.63)	< 0.001***	3.11	(2.09–4.61)	< 0.001***
Education level						
Informal education	1.34	(0.98–1.84)	0.069	0.66	(0.45–0.96)	0.031*
Elementary school	1.74	(1.31–2.31)	< 0.001***	1.39	(1.02–1.89)	0.037*
Middle school and above	1			1		
Marital status						
Married	1			1		
Separated, divorced, widowed, never married	1.70	(1.37–2.12)	< 0.001***	1.27	(0.98–1.66)	0.080
Living arrangemeny						
Not living alone	1			1		
Living alone	1.11	(0.80–1.53)	0.540	0.89	(0.62–1.28)	0.530
Residential area						
Urban	0.72	(0.54–0.97)	0.029*	0.71	(0.52–0.97)	0.031*
Suburban	0.89	(0.66–1.20)	0.450	0.94	(0.68–1.29)	0.700
Township	0.78	(0.57–1.05)	0.102	0.79	(0.57–1.08)	0.141
Rural	1			1		
Health status						
Depressive mood						
No	1			1		
Yes	3.03	(2.30–4.00)	< 0.001***	2.29	(1.69–3.10)	< 0.001***
Hearing						
Normal	1			1		
Loss	1.95	(1.49–2.54)	< 0.001***	1.50	(1.12–2.01)	< 0.001***
Vision						
Normal	1			1		
Impairment	0.71	(0.55–0.93)	0.013*	0.69	(0.52–0.92)	0.011*
CCI						
Score 0	1			1		
Score 1	1.39	(1.06–1.82)	0.020*	1.29	(0.97–1.71)	0.082
≥ Score 2	1.63	(1.26–2.11)	< 0.001***	1.41	(1.06–1.86)	0.018*

Note: [a] Adjusted for demographic characteristics and health status. * $p < 0.05$, *** $p < 0.001$.

of cognitive impairment due to the composite-measure approach used in this study.

We also found that, after adjusting for the potential confounders, older adults with an informal educational level had a 34% lower risk of cognitive impairment than those with a middle school or higher level of education. This finding differs from the previous studies that identified lower education level as a risk factor for cognitive function.[9,12] In this study, a relationship was found between cognitive function and health behaviors. Thus, engaging in more physical and social activities may reduce the risk of cognitive impairment, even in less-educated older adults.

Different health behaviors may affect the risk of cognitive impairment differently. However, as most of the participants in this study were cognitively intact (86.5%), educated to an elementary or higher level (70.9%), and between 65 to 74 years of age (57.3%), it was difficult to discern the discrete effects of different health behaviors at different levels of cognitive impairment. In addition, this study was limited by its use of cross-sectional data, which made it impossible to explore the trajectories of health behaviors and changes in cognitive status over time. In future studies, participants with various levels of impairment should be recruited and longitudinal data should be used to trace these trajectories in order to clarify the relationships between different health behaviors and cognitive impairment.

In conclusion, the results of this study indicate that, when clustered together, 14-item health behaviors are significant predictors of cognitive impairment. Programs that are designed to prevent cognitive impairment should focus particular attention on older adults with low levels of physical activity and social engagement.

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Conflict of interest

None.

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