Synergetic Effect of Physical Activity and Fruit-vegetable Intake on the Decreasing of Cognitive Decline in Older Taiwanese

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Abstract

Factors which are associated with cognitive decline among elders include physical activity and the intake of fruit and vegetable, however, long-term effects and the concurrence of physical activity and fruit-vegetable intake are unknown. The present study explores this potential synergy for the mitigation of cognitive decline among a cohort of older Taiwanese in a 16-year longitudinal study.

Five population-based surveys from the Taiwan Longitudinal Survey on Aging (1995–2015) involving 4,440 respondents over 53 years old in 1999 were studied. Trends in decrease of cognitive decline were observed for 16 years. Cognitive function was assessed using the Short Portable Mental Status Questionnaire (SPMSQ). Adjustments made on regression analysis included demographic, socioeconomic, health behavioral, and disease status covariates.

The risk of cognitive decline decreased 63% when high physical activity group and high intake of fruit-vegetable group were combined (OR :0.37, 95% CI: 0.23–0.59). More physical activity was combined with greater fruit-vegetable intake, cognitive decline among older Taiwanese was mitigated. This indicates that there may be a synergistic effect of physical activity and fruit-vegetable intake on mitigating cognitive decline. Synergistic personal behavior is a safe, effective, and economical approach to health in later life.

Introduction

World population is rapidly aging, over the age of 65 is estimated to increase to 12 % (about 1 billion) by 2030, and to 16.7 % (about 1.6 billion) in 2050[1]. The inability of elderly affects their daily life function, even affect individual's ability to effectively manage medications, leading to the deterioration of comorbid conditions such as heart disease or diabetes [2]. Cognitive decline has been considered a precursor of future cognitive decline [3]. Cognitive decline will cause the elderly to lose independence, reduce quality of life and bear the risk of premature death [4]. According to the Alzheimer's Association in the United States, medical expenditures due to cognitive decline over 65 years old in 2020 will be US$30.5 billion, and it is expected to exceed US$1.1 trillion by 2050[5].

The purpose of this study was to explore the correlation between the simultaneous increase of fruit-vegetable(F&V) intake and physical activity(PA) in the elderly in Taiwan and the decrease of cognitive decline. Despite there are no effective drugs to treat aging-related cognitive decline[6], previous studies have identified that PA is one of the effective ways to delay cognitive decline[7]. For example, PA effectively delay cognitive decline[8], high PA has higher and better protective effect on cognitive decline[9]. For elderly, PA has obvious benefits to the health outcomes, including improving cognitive function, reducing the risk of Alzheimer’s disease, and reducing neuropsychiatric symptoms [10-13]. However, lack of PA is one of the risk factors for cognitive decline among elderly [14]. Simple physical activities in daily life, such as a few amount of walking, also produce varying degrees of benefits to the health and cognitive function of the elderly [15, 16].

Intake of polyphenol-rich foods, such as fruits and vegetables, can be an alternative[17, 18]. F&V intake may be the main food for improving cognitive function[19]. Dietary factors play a key role in preventing cognitive decline. A large number of studies have confirmed the association between diet and cognitive function [20]. The elderly who consume a lot of F&V are significantly associated with the reduction of mild cognitive decline [21], and certain types of diets are associated with cognitive decline [22]. Previous studies have shown an association between Mediterranean-style diet patterns and specific nutrients against cognitive decline[23-27]. However, the current research still seldom explores the correlation and influence of the delay of cognitive decline when they occur simultaneously, and more evidence is needed for the impact of specific diets on cognitive decline[28].

Therefore, combining PA with F&V intake and delaying cognitive decline to analyze the effect will be able to simultaneously explore the effects of two or more variables. This research will provide the elderly with specific and easy-to-implement diet and exercise recommendations in daily lives.

Methods

Data and Sample

The data come from the Taiwan Longitudinal Survey on Aging (TLSA). This project was jointly implemented by the Taiwan Health Promotion Administration and the Population Studies Center of the University of Michigan, and funded by the US National Institute on Aging and the government of Taiwan [28]. The TLSA survey is to understand the impact of demographic, socio-economic, environment and lifestyle changes on the health, healthcare use and cognitive status of older Taiwanese. A three-stage proportional probability sampling technique is adopted, and the sampling frame is based on household registration data. Face-to-face interviews by trained interviewers were conducted. TLSA uses measurement scales commonly used in population-based research and is known for its high completion rate and acceptable data quality [29]. The detail information of study design and sampling of TLSA has been described previously by the present authors and by Zimmer et al [30, 31].

This study explored longitudinal trends in cognitive status by using five wave population-based surveys conducted over a 16-year timeframe (1999–2015). The 1999 survey contained data on diet and nutrition, and was therefore chosen as the baseline of the present study. Data from 1999 (baseline), 2003, 2007, 2011 and 2015 were utilized and a categorical variable was created to distinguish data. During the follow-up period, the number of missing and dead increased. The respondents in each year as follows: 4197 (in 1999), 3386 (in 2003), 2712 (in 2007), 2047 (in 2011), 1491 (in 2015) respondents who completed five wave interviews and self-report were included in the analysis (Fig.1). The protocol of TLSA was reviewed and approved by government-appointed representatives and the study was conducted according to ethical standards set forth in the Helsinki Declaration. All participants gave informed consent.

This study analyzed datasets from 1999 to 2015. Of the 4,400 eligible older adults, we excluded individuals due to missing data for either the Chinese version of Short Portable Mental Status Questionnaire (SPMSQ) or sensory decline items. We excluded 243 individuals with cognitive declines as defined by receiving SPMSQ scores ≤6 during their initial assessments in 1999. Exclusion of older adults with cognitive declines could ensure the accuracy of the responses in the initial assessments which may be influenced by cognitive status. Ultimately, data from 1491 older adults without cognitive declines were included for analysis.

Outcome measure

The SPMSQ (with a score range of 0-10) was used to score cognitive status [32]. The questionnaire is usually used for older adults in Taiwan and has good test-retest and half-half reliability (r = 0.70, α = 0.72), the sensitivity was between 50% and 82%, and the specificity is 90 % (33). The SPMSQ consisted of 10 items: (i)What are the date, month, and year? (ii)What is the day of the week? (iii)What is the name of this place? (iv)What is your phone number? (v)How old are you? (vi)When were you born? (vii) Who is the current president? (viii)Who was the president before him? (ix) What was your mother's maiden name? (x) Can you count backward subtract 3 from 20 four consecutive times? Total adjusted scores ranging from 0 to 10, higher score indicated poorer cognitive function. One more error was allowed in the scoring if a participate has had a grade school education or less. One less error was allowed if the participate has had education beyond the high school level [33]. Participants with two or more errors than each former wave survey score were described as having cognitive decline [34].

Independent variables

The measurements of PA involved frequency, duration and intensity which were adopted from World Health Organization (WHO), Haaseet et al. and Pitsavos et al. [35-37]. Three questions were included: (i) How often do you do engage in routine physical activity? The choices provided were (a) none (invalid), (b) <2 times a week, (c) 3–5 times a week, and (d) ≥6 times a week; (ii) How many minutes do you spend each time? The choices provided were (a) <15 minutes/time, (b) 15–30 minutes/time, and (c) ≥30 minutes/time; (iii) After you exercise will you sweat or gasp? The choices provided were (a) no sweating or gasping and (b) some or much sweating or gasping. The scores of the three indices were multiplied to attain the PA score for each participant. The total score ranges were from 0 to 18. PA was divided into three levels: low (total score = 0), moderate (total score = 1-7), and high (total score = 8-18). The definition of PA does not include work-related activities or activities of daily living, and the reliability has generally acceptable [37, 38].

The intake of F&V was evaluated based on a validated semiquantitative questionnaire that assesses the frequency of intake of food categories. The frequency of intake of F&V was calculated by: every day or almost every day as 6 times, 3 to 5 times a week as 4

times, 1 to 2 times a week as 1.5 times, less than once a week as 0.5 times, and do not eat as 0 times; the total number was divided into three groups: low (<7 times a week),moderate (7-9 times a week), high (≥10 times a week).

PA and F&V intake variables were combined and divided into five groups: both low (no PA and the weekly F&V intake was less than 7 times), both high (high PA and the weekly F&V intake was ≥10 times), only high PA (high PA and the weekly F&V intake was <7 or 7-9 times), only high F&V intake(the intake of F&V was ≥10 times per week and no or moderate PA), and others (only or at the same time with low PA or 7-9 times per week of intake of F&V).

Covariates

Time-varying covariates of several indicators of health behaviors and concurrent health indicators adjusted logistic regression were used to explore the association between each variable of interest and cognitive decline. Education adjustment score was applied for three groups, ≦6 years,7-12 years, and ≧13 years. Drinking was divided into two groups: never drinking and drinking once or more a week (yes vs no); smoking was divided into two groups: non-smoker or current and past smokers (yes vs no); tea consumption was divided into two groups: three or more times and less than three times a week. Chronic diseases, such as hypertension, diabetes, heart disease, stroke and cancer were according to whether a physician had told the respondent they had the disease. Depressive symptom was measured by Depression Short Form (CES-D-10) [28, 39], a 10-item Likert scale questionnaire assessing depressive symptoms, based on self-reports during the past week. The total score was 0 to 30, and ≥10 was considered as having depressive symptoms (yes vs no). Life Satisfaction Index (LSI) [40] (total score range was 0–10) was used to assess life satisfaction, ≥6 was considered as satisfied with life [38,41], and higher scores indicated higher level of life satisfaction.

Data analysis

All statistical analyses were carried out with the SPSS statistical software package version 22.0. Generalized estimating equations (GEE) with robust standard error estimates were used to consider within-subject correlations during the 16-year follow-up period [42,43]. Data from 1999(baseline), 2003, 2007, 2011 and 2015 five wave follow-up interviews were assessed simultaneously in all analyses. The baseline measures of cognitive status were included to reduce unobserved heterogeneity. Given the considerable changes to social economic status, family structure, and physical health at the end of the life course, we assessed the robustness of these associations over time. The longitudinal models included measures of cognitive status from previous waves to examine associations between PA, F&V intake and subsequent cognitive status. All values were weighting adjusted according to study design.

Results

Demographic characteristics at baseline and the sixteen-year follow-up. Table 1 presents the essential characteristics of the dataset. The participants in the baseline in 1999 were 4,197. Male (51.0%) was more than female (49.0%), 61.2 % most of them were 53-64 years old,75.2 % had formal education of ≦6 years, 7.0% were educated more than 13 years. Male has less proportion of cognitive decline than female (11.4% vs. 22.8%). Most of the participants reported being married (79.2%), no smoking (78.6%), no drinking (72.0%); 27.8% participants were diagnosed with hypertension, other chronic diseases were reported such as diabetes (8.0%), heart disease (14.6%), stroke (1.7%), cancer (2.1%) and 12.6% had depression symptoms. The majority of participants feel satisfied with life (64.0%). Over half of male (53.1%) were high PA, the proportion of female in the low PA group was higher than that of male. The ≧75 years old group of high PA, 53-64 years old group of high F&V intake had the highest proportion (65.3% and 80.9%), when we combined PA and F&V intake groups, the 65-74 years old group of the both high group showed the highest proportion (49.0%). In the educated years≧13 group, 15.2 % reported low PA and was lower than the other two educated years groups, furthermore, it reported the highest proportion of high PA (64.8%), high F&V intake (94.3%), and combined PA and F&V intake groups (61.9%). Regardless of whether the participants were married or not, the proportion of low PA was more than one-third (39.4% and 39.0%), however, the high PA group were the most (49.8% and 47.1%); married participants had higher proportion as three followed groups: high F&V intake, both high, and only F&V high. Among smokers, the proportion of low PA (45.5 %) was higher than that of the moderate and the high PA group, more than half of non-smokers were high PA (50.9%), high F&V intake (83.6%), and both high (41.9%). The drinking group had high PA were 51.9%, which was higher than no-drinking/high PA group (48.2%), moreover, it showed lower proportion with drinking group of high F&V intake. Participants of high PA, high F&V intake and both high were 55.2%, 85.7% and 48.3% feel satisfied

with life. Participants reported unsatisfied with life had higher proportion of cognitive decline in the baseline (1999). The association between chronic diseases and cognitive decline among older Taiwanese showed no statistical significance.

Table 2 shows the results of cognitive decline from 2003 to 2015. Compared with male, cognitive decline of female was lower overall and with an average from 0.3% to 11.4%.

Figure 2(a) reported significant difference of multiples odds ratio (OR) ($p < 0.01$) was identified, regardless of gender and whether high PA or low PA. The OR of female was 0.39 ($p < 0.01$), and the multiple OR of male was 0.32 ($p < 0.01$) better than the female in decreasing cognitive decline. High F&V intake and low F&V intake both had multiple significant cognitive decline differences. Among them, the female OR was 0.50, and the male OR was 0.47 ($p < 0.01$) also better than the female, as shown in Figure 2(b). Figure 2(c) shows that combining high PA and high F&V intake, lower PA and low F&V intake had multiple significant differences in cognitive decline ($p < 0.01$), the combined OR for female was 0.37 to 0.98, and male were more effective than female, and its OR was 0.27 to 0.48.

Table 3 presents the impact of the participants' PA and F&V intake at the reference point on the cognitive decline of old Taiwanese after 16 years, and GEE (Generalized Estimated Equation) regression was adopted. Gender, age, education, marriage, smoking, drinking, high blood pressure, heart disease, diabetes, cancer, stroke, CES-D and LSI were controlled. In model 1, the study shows significant results ($p < 0.05$), with OR value of 0.40 and 0.58 folds which means moderate and high PA can decrease 60% and 42% the cognitive decline respectively, moreover, high F&V intake also reported decrease of cognitive decline of old adults by 40 %, significantly. The moderate F&V intake decreased the cognitive decline of older adults by 0.86 folds. Although it was not significant ($p = 0.202$), the trend was consistent. Model 2 also presents the effects of combing PA and F&V intake on the old adults' cognitive decline in the 16 years of tracking. Compared with the both low group, the both high group was decreased by 63% ($p < 0.00$), only F&V high group decreased by 45% ($p <0.00$), only PA high group and others group decreased by 40% and 23%, and showed no significance ($p > 0.05$). The results suggest that both high group (the intake of F&V more than ten times per week combined with PA < 2 times a week, 15–30 minutes/time and some or much sweating or gasping), and the only high F&V intake group can effectively decrease Taiwanese adults' cognitive decline.

Discussion

This study examined the synergistic effect of PA and F&V intake on cognitive decline in older Taiwanese. Independently, high PA and high intake of F&V were associated with decreased likelihood of the risk of cognitive decline. When PA and F&V intake were combined, the simultaneous of high PA and high F&V intake significantly reduce the risk of cognitive decline as high as 63% in older Taiwanese.

Presently, it is known that PA and F&V intake are widely recommended health behavior. F&V intake have been independently proved with reduced risk of diabetes, stroke, heart disease and cognitive functional decline [44–47]. As well, although much work has been done to explore the relationship between PA and cognitive function, this relationship has been mainly explored in older adults [48, 49]. To date, very little is known about the combined effect of PA and F&V intake and cognitive function, in older Asian adults.

The present study adds significant and creative information as follows. First, the results support important findings of the synergistic effects of PA and F&V intake on decreasing cognitive decline in Taiwan, and showed that PA and F&V intake play a vital role in improving the older Taiwanese's cognitive functions. PA and F&V intake are predictors of cognitive decline and negatively related to the cognitive risk of the elderly. We argue that PA and the intake of F&V simultaneously are beneficial to decreasing cognitive decline. Practicing these habits at the same time brings more significant health benefits than practicing them alone. In the present study, F&V intake was not independently related to cognitive decline. Compared with high PA and high intake of F&V separately, the risk of cognitive decline decreased 63% when high PA and high intake of F&V were combined. Unlike western countries with highly PA habits and facilities, Asians used to have fewer PA habits due to lack of insufficient facilities [50].

Second, the study reported an important longitudinal result of the national population-based cohort study of cognitive functions in older Taiwanese. To our knowledge, this is the pioneer study that explore the 16-year longitudinal relationship between PA and F&V intake of older adults in Taiwan. Third, the generalized estimating equations (GEE) models used herein to analyze the longitudinal data during the 16-year follow-up period. GEE for this study are a convenient and general approach to the analysis of several kinds of

correlated data. The main advantage of GEE resides in the unbiased estimation of population-averaged regression coefficients despite possible misspecification of the correlation structure [42, 43].

Although the mechanism of the positive effect of PA and F&V intake on cognitive decline is unclear, there are several possible mechanisms for the cognitive decline. The first is our research results show that high PA can effectively reduce the risk of subsequent cognitive decline. This finding is consistent with many previous studies. Daily PA has been found to prevent cognitive decline in the elderly and help delay the cognitive decline that they already have; the severity of the elderly, PA is one of the risk factors for cognitive decline and associated with better cognitive performance [51–53]. Different kinds of sports lead to mental stimulation properties, such as the need for eye-hand coordination and visual and spatial memory, which further enhance their impact on cognitive function [54]. In 2018, 26 researchers representing nine countries and a variety of academic disciplines met in Snekkersten, Denmark, to reach evidence-based consensus about PA and older adults. They presented the consensus on the effects of PA on older adults' fitness, health, and cognitive functioning, functional capacity, engagement, motivation, psychological well-being and social inclusion[6].Studies have also suggested that the reason why exercise has the effect of preventing dementia may be related to the stimulation of neurotrophic factor (brain-derived neurotrophic factor, BDNF) secreted by the brain, which can prevent the hippocampus from shrinking and maintain cognitive function. In daily life, we perceive external stimuli through our eyes, ears, tongue, nose, and skin. These perceptions can be roughly divided into five types: sight, hearing, taste, touch, and smell, which are also called the "five senses." PA can promote the activity of our five senses. At the same time, proper PA is also very helpful to prevent dementia and restore cognitive function [55, 56]. This is the same result that this study found that PA is a protective factor and high PA helps reduce the risk of cognitive decline.

Second, the analysis in this study found that high F&V intake is an important factor in significantly reducing the risk of cognitive decline. The results of recently published integrated analysis studies consistently found that increased intake of F&V, is associated with a decrease in the risk of cognitive decline. This finding is in line with recent studies, indicating that diet plays a related role in people's cognitive decline. Foods rich in antioxidants, such as fruits, vegetables, and nuts, can improve the prevention or delay of the occurrence of cognitive decline, higher intake of is related to reducing or preventing cognitive decline [47, 57]. There are many known protective mechanisms, such as polyphenolic compounds in many plant foods, and bioactive compounds in various fruits, vegetables, legumes, nuts and whole grains, including antioxidants, vitamins, and polyphenols. Other phytochemicals and unsaturated fatty acids, by reducing oxidation, can enhance synaptic plasticity and neuron survival [58, 59], alleviate cognitive decline, help cognitive health, and improve specific cognitive areas (especially the frontal lobe executive function). Polyphenols in fruits and vegetables can regulate tau hyperphosphorylation and β-amyloid aggregation in animal models of Alzheimer's disease [60, 61]. Taken together, for the elderly, the different nutrients contained in fruits and vegetables can reduce the risk of cognitive decline. Third, this study also has a multiplier effect on cognitive decline by "combining high F&V with high PA", which can reduce the risk of dementia by 67%; further evidence is strengthened to support the impact of the combination of PA and F&V intake on cognitive decline .

Why PA and F&V have synergy? According to Walker and Avant's health literacy concept analysis [62], elderly people with health literacy pay more attention to health and are more diligent in acquiring, understanding and applying health information or knowledge. Factors, personal factors, and situational factors may change, but such elderly people understand that they are in a state of degraded physical, mental, and social functions. Their health literacy will encourage them to develop the habit of physical activity simultaneously and focusing on ingesting fruits and vegetables to achieve self their purpose of health management, health care and prevention of cognitive decline[63].The elderly in Asia and Taiwan, because young urbanites are busy at work, they generally have bad habits such as eating imbalance and lack of exercise, and the risk of chronic diseases in their later years will also increase [64]. Because the body is getting older and paying attention to health, both PA and F&V intake are healthy behaviors that require continuity and discipline, and gradually develop exercise and diet habits in life, so a healthy attitude towards PA and F&V intake is more important. According to research by Harooni et al.[65], regular healthy living habits and healthy living discipline are very important for the elderly. Both PA and F&V intake require regular and disciplined maintenance in order to have good health effects, healthy and successful aging, and prevent cognitive decline is the best proof.

PA and nutrition have complementary effects, and there are risks if they are separated. As far as cognition was concerned, according to the results of a survey in Taiwan [66], the most common physical activities were: walking (69.6%), gymnastics (14.9%) and hand-shaving (8.5%). It can be seen that PA of the elderly stay in low-intensity and low-resistance had less health-promoting effects, and most of them were engaged in simpler physical activities in parks or schools near their homes [66]and intensity of PA was

insufficient. Nutrient supplements with F&V are needed to reduce the risk of cognitive decline. Conversely, although a great amounts of F&V intake can increase the nutritional content, if without cooperate with PA, the effect of preventing cognitive decline will be reduced to 40% and 23%.

This study has limitations. Cognitive decline was not diagnosed by physicians but self-reported by the elderly. Although it has acceptable accuracy, it inevitably has some shortcomings. The cognitive status of this study was based on the topics of the Chinese version of the SPMSQ scale, which was widely used in domestic studies, and its reliability and validity had also been confirmed. This study used a relatively long period of time between 1999 and 2015, which lasted for 16 years. As dietary and physical activity may change with age, health status, social environment and other factors. The research subjects were elderly people in Taiwan, so the results may not be applicable to younger Taiwanese. Furthermore, data was collected for frequency of intake without quantity (such as servings or serving sizes), so food intake cannot be quantified.

Conclusions

Intake of PA and F&V have a negative correlation with cognitive decline. High F&V intake and high PA can effectively reduce the risk of cognitive decline among elderly people in Taiwan. This result highlights the importance of F&V intake and PA for elderly people in Taiwan to reduce cognitive decline and maintain long-term health. For the elderly, it is restricted by physical function (tolerance, cardiopulmonary function, muscle strength, etc.), even the general environment such as climate, temperature, light, etc.). Therefore, it is necessary to accumulate the amount of regular PA every day, arranging a certain amount of F&V intake in each meal of the day, and practicing the daily PA is the easiest and most likely to achieve, which helps to reduce cognition decline. The advanced our understanding of the combined effect on cognitive decline, implying strategies or interventions for improving cognitive functions among older adults should consider individual health-related factors.

Declarations

Data availability

The data that support the findings of this study are available from the Health Promotion Administration of the Department of Health & Welfare of Taiwan but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data are however available from the authors upon reasonable request and with permission of the Health Promotion Administration of the Department of Health & Welfare of Taiwan. The study clarified that the data used in this study was anonymized. Ethical approval was obtained from Institutional Review Board of Tri-Service General Hospital, National Defense Medical Center (TSGHIRB No. B-109-30).

Competing interests

The authors declare that they have no competing interests.

Author contributions

R.S.W. designed the study; R.S.W. and Y.N.H. drafted the manuscript; B.L.W. directed the study and reviewed the manuscript; R.S.W. and B.L.W. directed statistical analysis and helped interpret the results. T.T.H.W edited the paper and suggested the future direction for further investigation, all authors reviewed and approved the manuscript.

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Tables

Table 1

Characteristics of participants at baseline of the TLSA (1999); PA physical activity; FV Fruit-Vegetable intake; Depressive Symptoms (CED-10≧10).

		Physical activity (%)			Fruit-vegetable intake (%)			Combine physical activity and fruit-vegetable intake (%)					Cognitive decline(%)
		Low	Moderate	High	Low	Moderate	High	Both Low	Both High	Only PA High	Only FV High	Other	Yes
Gender (%)													
Male	51.0	35.7	11.2	53.1	10.9	11.4	77.7	5.3	42.7	8.5	34.7	8.8	11.4
Female	49.0	42.8	11.7	45.5	7.9	9.8	82.3	3.6	37.6	4.9	44.3	9.6	22.8
Age (%)													
53-64	61.2	46.3	12.6	41.1	8.5	10.7	80.9	4.5	34.6	5.2	45.9	9.8	13.6
65-74	32.1	29.1	9.6	61.3	10.7	8.8	80.4	4.2	49.0	7.9	31.0	7.9	22.8
≧75	6.8	24.8	9.9	65.3	10.9	17.8	71.3	5.0	47.5	13.9	23.8	9.9	22.8
Education (%)													
≦6	75.2	45.3	10.2	44.5	10.9	12.4	76.7	5.2	34.2	7.3	42.2	11.2	19.4
7-12	17.8	23.4	13.6	63.0	5.7	5.7	88.6	2.3	56.6	5.7	31.7	3.8	7.5
≧13	7.0	15.2	20.0	64.8	1.9	3.8	94.3	1.9	61.9	1.9	32.4	1.9	17.1
Marital status (%)													
Yes	79.2	39.4	10.8	49.8	8.5	9.9	81.6	3.9	40.8	6.5	40.5	8.3	15.6
No	20.8	39.0	13.9	47.1	12.7	13.0	74.4	6.5	37.4	7.1	36.5	12.6	23.2
Smoking (%)													
Yes	21.4	45.5	11.6	42.9	17.0	15.8	67.2	10.3	33.5	10.0	33.2	12.9	10.7
No	78.6	37.6	11.4	50.9	7.3	9.2	83.6	2.8	41.9	5.7	41.4	8.2	18.9
Drinking (%)													
Yes	28.0	35.4	12.7	51.9	13.3	9.9	76.9	6.2	41.6	10.0	34.7	7.4	10.8
No	72.0	40.8	11.0	48.2	7.9	10.8	81.3	3.7	39.5	5.3	41.6	9.9	19.7
Hypertension (%)													
Yes	27.8	29.7	13.0	57.2	8.0	9.4	82.6	2.4	47.1	6.5	35.3	8.7	17.9
No	72.2	43.0	10.9	46.1	9.9	11.0	79.1	5.2	37.4	6.7	41.3	9.4	16.9
Diabetes (%)													
Yes	8.0	31.7	16.7	51.7	7.5	8.3	84.2	3.3	42.5	1.7	41.7	10.8	23.3
No	92.0	40.0	11.0	49.0	9.5	10.8	79.7	4.5	39.9	7.1	39.5	9.0	16.6
Heart disease (%)													
Yes	14.6	33.6	16.6	49.8	9.8	12.1	78.1	6.0	41.5	6.0	35.9	10.6	19.8
No	85.4	40.3	10.6	49.1	9.3	10.3	80.4	4.2	39.9	6.8	40.3	8.9	16.7
Stroke (%)													
Yes	1.7	44.0	8.0	48.0	12.5	4.2	83.3	8.0	36.0	8.0	44.0	4.0	12.0
No	98.3	39.2	11.5	49.2	9.3	10.7	80.0	4.4	40.2	6.6	39.6	9.3	17.3
Cancer (%)													

		Physical activity (%)			Fruit-vegetable intake (%)			Combine physical activity and fruit-vegetable intake (%)					Cognitive decline(%)
		Low	Moderate	High	Low	Moderate	High	Both Low	Both High	Only PA High	Only FV High	Other	Yes
Yes	2.1	25.0	18.8	56.3	12.5	3.1	84.4	3.1	50.0	3.1	34.4	9.4	15.6
No	97.9	39.6	11.3	49.1	9.3	10.7	80.0	4.5	39.9	6.7	39.8	9.2	17.2
Tea consumption (%)													
<3	64.1	40.7	11.8	47.5	10.3	10.7	79.1	4.3	37.5	6.7	41.3	10.1	19.5
≧3	35.9	36.8	10.7	52.4	7.7	10.5	81.8	4.3	44.7	6.6	37.0	7.3	13.2
Depressive symptoms (%)													
No	87.4	37.3	10.0	52.7	7.9	10.2	81.8	3.5	43.5	7.0	38.1	8.0	15.7
Yes	12.6	48.3	17.8	33.9	21.4	10.4	68.2	10.3	23.0	6.9	44.8	14.9	25.3
Life satisfaction (%)													
Un-satisfied	36.0	45.7	11.9	42.3	14.3	14.1	71.6	7.7	30.6	8.7	40.5	12.6	21.7
Satisfied	64.0	34.4	10.3	55.2	6.8	7.5	85.7	2.3	48.3	5.5	37.3	6.7	14.9

Table 2

Demographic characteristics and cognitive decline of Taiwan Longitudinal Survey on Aging (TLSA) from 2003 to 2015.

TLSA Year			2003 (n=3,386)		2007 (n=2,712)		2011 (n=2,047)		2015 (n=1,491)	
Cognitive Decline			**No**	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**	**Yes**
Gender (%)	Male	51.0	99.7	0.3	92.4	7.6	95.2	4.8	88.6	11.4
	Female	49.0	98.9	1.1	79.9	20.1	85.7	14.3	77.2	22.8
Age (%)	53-64	61.2	99.5	0.5	88.2	11.8	92.2	7.8	86.4	13.6
	65-74	32.1	99.0	1.0	84.5	15.5	87.4	12.6	77.2	22.8
	≧75	6.8	100.0	0.0	73.4	26.6	87.1	12.9	77.2	22.8
Education (%)	≦6	75.2	99.3	0.7	83.5	16.5	88.2	11.8	80.6	19.4
	7-12	17.8	100.0	0.0	95.4	4.6	97.4	2.6	92.5	7.5
	≧13	7.0	98.1	1.9	89.2	10.8	95.2	4.8	82.9	17.1
Marital status (%)	Yes	79.2	99.5	0.5	88.2	11.8	91.9	8.1	84.4	15.6
	No	20.8	98.7	1.3	78.0	22.0	84.5	15.5	76.8	23.2
Smoking (%)	Yes	21.4	99.4	0.6	90.7	9.3	93.1	6.9	89.3	10.7
	No	78.6	99.3	0.7	84.8	15.2	89.6	10.4	81.1	18.9
Drinking (%)	Yes	28.0	100.0	0.0	93.3	6.7	93.5	6.5	89.2	10.8
	No	72.0	99.1	0.9	83.2	16.8	89.1	10.9	80.3	19.7
Hypertension (%)	Yes	27.8	99.0	1.0	85.5	14.5	88.9	11.1	82.1	17.9
	No	72.2	99.4	0.6	86.3	13.7	90.9	9.1	83.1	16.9
Diabetes (%)	Yes	8.0	97.5	2.5	82.9	17.1	84.2	15.8	76.7	23.3
	No	92.0	99.5	0.5	86.3	13.7	90.9	9.1	83.4	16.6
Heart disease (%)	Yes	14.6	98.6	1.4	83.1	16.9	88.0	12.0	80.2	19.8
	No	85.4	99.5	0.5	86.6	13.4	90.7	9.3	83.3	16.7
Stroke (%)	Yes	1.7	100.0	0.0	92.0	8.0	88.0	12.0	88.0	12.0
	No	98.3	99.3	0.7	86.0	14.0	90.4	9.6	82.7	17.3
Cancer (%)	Yes	2.1	96.9	3.1	77.4	22.6	87.5	12.5	84.4	15.6
	No	97.9	99.4	0.6	86.3	13.7	90.4	9.6	82.8	17.2
Tea consumption (%)	<3	36.0	99.3	0.7	84.4	15.6	88.0	12.0	80.5	19.5
	≧3	64.0	99.4	0.6	89.2	10.8	94.4	5.6	86.8	13.2
Depressive symptom (%)	No	64.1	99.4	0.6	87.7	12.3	90.7	9.3	84.3	15.7
	Yes	35.9	98.3	1.7	78.1	21.9	85.6	14.4	74.7	25.3
Life satisfaction	Un-satisfied	87.4	99.4	0.6	80.0	20.0	85.2	14.8	78.3	21.7
	Satisfied	12.6	99.2	0.8	89.3	10.7	93.2	6.8	85.1	14.9

Table 3

Adjusted longitudinal associations of physical activity and fruit-vegetable intake on cognitive decline in older Taiwanese of Taiwan Longitudinal Survey on Aging from 1999 to 2015.

		Model 1		Model 2	
		OR	95% CI	OR	95% CI
Physical activity	High	0.40	0.30-0.52		
	Moderate	0.58	0.32-1.02		
	Inactive	1			
Fruit-vegetable intake	High	0.60	0.41-0.84		
	Moderate	0.86	0.53-1.37		
	Low	1			
Combine physical activity (PA) and fruit-vegetable(F&V) intake	Both High			0.37	0.23-0.59
	PA High Only			0.60	0.34-1.05
	FV High Only			0.55	0.35-0.87
	Others			0.77	0.44-1.33
	Both Low			1	
Gender	Male	1		1	
	Female	0.55	0.40-0.74	0.55	0.41-0.75
Age	53-64	1		1	
	65-74	11.75	5.38-25.63	11.71	5.41-25.32
	≧75	33.91	15.63-73.57	36.94	17.20-79.29
Education (Years)	≦6	1		1	
	7-12	0.40	0.24-0.64	0.39	0.24-0.62
	≧13	1.33	0.75-2.35	1.25	0.71-2.19
Marital Status	Yes	0.80	0.61-1.04	0.78	0.60-1.00
	No	1		1	
Smoking	Yes	0.67	0.43-1.03	0.67	0.44-1.02
	No	1		1	
Drinking	Yes	0.92	0.63-1.33	0.89	0.62-1.28
	No	1		1	
Hypertension	Yes	1.08	0.84-1.40	1.11	0.87-1.43
	No	1		1	
Diabetes	Yes	1.72	1.25-2.36	1.74	1.27-2.40
	No	1		1	
Heart Disease	Yes	0.93	0.70-1.23	0.92	0.70-1.22
	No	1		1	
Stroke	Yes	2.00	1.32-3.03	2.19	1.45-3.32
	No	1		1	
Cancer	Yes	1.16	0.64-2.10	1.14	0.64-2.04
	No	1		1	

		Model 1		Model 2	
		OR	95% CI	OR	95% CI
Tea consumption	<3	0.90	0.67-1.22	0.90	0.68-1.22
	≧3	1		1	
Depressive symptoms	Yes	1.56	1.21-2.03	1.67	1.28-2.17
	No	1		1	
Life satisfaction	Satisfied	0.90	0.70-1.16	0.87	0.68-1.12
	Unsatisfied	1		1	

Figures

Figure 1

Participants in serial surveys in the TLSA from 1999 – 2015.Missing is incomplete data on major constructs.

Figure 2

The differences in (a)physical activity, (b)fruit and vegetable intake, (C)combine physical activity and fruit and vegetable intake in gender. Bars show 95% CIs.