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Transitions of self-management behaviors and frailty status among community-dwelling older adults: a national longitudinal population-based cohort study

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Abstract

Background: Frailty in older adults is a common geriatric syndrome that could be prevented; thus, coping strategies for the aging population are essential. Self-management behaviors may represent cost-effective strategies to prevent physical frailty in community-dwelling older adults. This study aimed to describe the changes in frailty status among community-dwelling older adults in Taiwan and investigate the association between transitions of self-management behaviors and frailty status over 4 years of follow-up (2007 to 2011).

Methods: Data were retrieved from the Taiwan Longitudinal Study of Aging (TLISA), years 2007 and 2011. In this prospective cohort study, 1283 community-dwelling older adults aged 65 years and older without cognitive impairment were recruited. Frailty was defined based on Fried's frailty phenotype. Self-management behaviors (maintaining body weight, quitting smoking or no smoking, drinking less or no drinking, exercising, keeping diet control, and maintaining a regular lifestyle) were assessed using a questionnaire. Multinomial logistic regression analyses were used to investigate the associations between changes in self-management behaviors and in frailty status. The age group was further stratified to examine the moderation effect in the relationship between changes in self-management behaviors and in frailty status among older adults.

Results: The prevalence of frailty was 8.7% at baseline and 14.9% after 4 years of follow-up, with 196 (15.3%) deaths. Overall, 514 (40.1%) participants maintained their frailty status, 424 (33.0%) worsened, and only 149 (11.6%) improved. Being aged ≥ 75 years old, having chronic diseases, and an absence of self-management behaviors were associated with frailty at baseline and after follow-up. Among individuals aged 65–74, compared to those who maintained no self-management behaviors, those who decreased the exercise behaviors (yes-to-no) had a higher risk of worsening (RRR = 2.518), while increasing (no-to-yes) and maintaining (yes-to-yes) frequent physical exercise were associated with a lower risk of worsening (RRR = 0.466 and 0.572, respectively) than stable frailty; those who maintained body weight (yes-to-yes) were associated with a lower risk of worsening (RRR = 0.327) than stable frailty after controlling for individual covariates and chronic diseases. Among individuals over 75 years old, compared to no exerciser, older

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old who decreased their physical exercise had a higher risk of frailty worsening ($RRR = 3.255$), and increasing frequent physical exercise (no-to-yes) was associated with an improvement in frailty status ($RRR = 3.684$). Age was a moderator between the effects of maintaining body weight on frailty worsening. There were no associations between the behavioral transitions of smoking, drinking, diet control, or regular lifestyle on the frailty status changes.

Conclusions: Maintaining body weight and frequent physical exercise increased the ratio of frailty stability among individuals 65–74 years old. Increasing exercise behavior is the only factor to improve their frailty status among older adults aged 75 years and over. Older adults should be encouraged to perform adequate physical exercise and maintain a healthy body weight to maintain the frailty status in younger old aged 65–74 years, and especially perform more frequent exercise to improve frailty status in older old over 75 years.

Keywords: Frailty, Older adults, Community-dwelling, Self-management behavior

Background

Populations throughout the world are aging rapidly. About 14.5% of the population were aged ≥ 65 years old in 2018, and this rate is predicted to increase to 20.7% by 2026 in Taiwan [1]. Frailty is a clinical syndrome characterized by functional impairment and vulnerability to stressors [2]. It is a precursor to disability [3] and increases the risk of various adverse health outcomes, such as falls, fractures, dependency, hospitalization, and mortality [4]. However, frailty is a dynamic process involving frequent transitions to states of greater or lesser frailty over time [5–7]. The transitions between frailty states were first reported by Gill et al. [5], who assessed 754 community-living adults aged 70 years or older every 18 months over a period of 54 months. Overall, 57.6% of the individuals experienced at least one frailty transition, and participants were more likely to transition to states of greater frailty (43.3%) than lesser frailty (23.0%) [5]. A subsequent meta-analysis of 16 cohort studies that examined frailty transitions reported that 40.6% (95% CI: 36.7–44.7%) of individuals transitioned from non-frail to pre-frail, 18.2% (95% CI: 14.9–21.7%) from prefrail to frail, and only 3.3% (95% CI: 1.6–5.5%) transitioned from frail to non-frail over a mean follow-up of 3.9 years [8]. Therefore, more attention should be paid to the factors associated with the change in frailty status in order to identify measures to prevent the progression of frailty.

A broad range of risk factors is associated with the prevalence of frailty, including sociodemographic, clinical, lifestyle, psychological, and biological factors [9]. Healthy lifestyle behaviors are recognized as factors associated with preventing frailty [10–12]. Multifactorial interventions, including physical exercise, nutrition, psychosocial programs, and cognitive training, effectively improve functional health and frailty among adults over 65 years old [13, 14]. Moreover, previous observations found that underweight, overweight, or obese people were at higher risk of becoming frailty and had a higher mortality risk [12, 15]. Prolonged smoking may also increase the likelihood of frailty and death [16]. In

contrast, low-moderate alcohol drinking (≤ 2 drinks per day for men) was associated with improvements in frailty status among frail or pre-frail individuals at baseline [12].

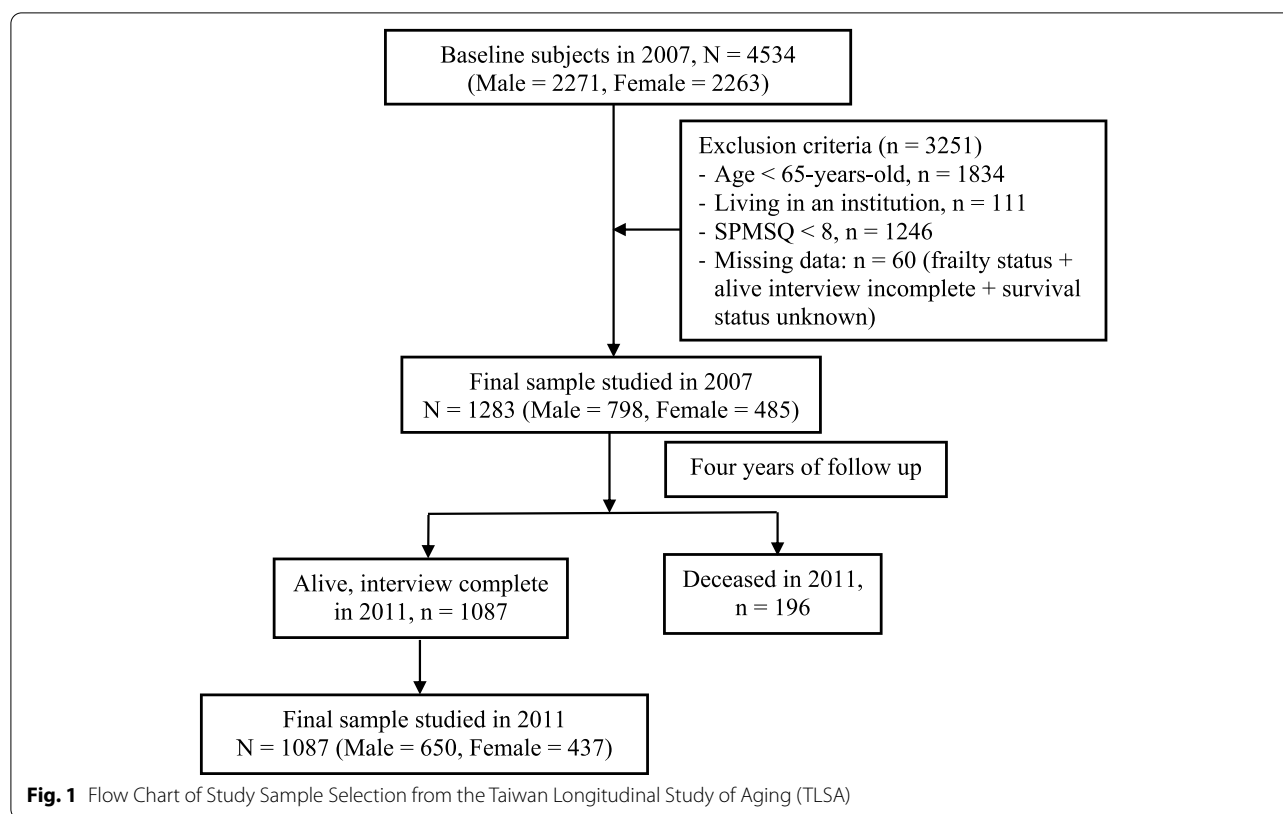
Thus, it is necessary to evaluate the long-term effects of self-management behaviors, including maintaining body weight, quitting smoking or no smoking, drinking less or no drinking, exercising, keeping diet control, and maintaining a regular lifestyle, on changes in frailty status. However, at present, relatively scarce data on the associations between these factors in the prevention of frailty are available. We used a national survey to investigate the relationships between changes in frailty status and in self-management behavior over time with various covariates of individual characteristics. A 4-year national longitudinal population-based cohort study was conducted to describe the changes in frailty status in community-dwelling older adults in Taiwan and investigate the effect of changes in self-management behaviors on changes in frailty status.

Methods

Source of data and participants

The Taiwan Longitudinal Study on Aging (TSLA) is a national representative population-based cohort study conducted by the National Institute of Family Planning (1965–2000) and The University of Michigan's Population Studies Centre (PSC), funded by The National Institute on Aging (NIA) and the Government of Taiwan [17]. The TSLA began in 1989 with follow-up periods of 3 to 4 years. Data are collected from participants aged 60 or older using a self-reported questionnaire through face-to-face interviews, with high response rates of 88.3 to 92% in Wave I to Wave VII. More details of the TSLA sample design and data collection were provided in a previous study [18].

This study analyzed data from the cohorts surveyed in 2007 and 2011; details of these cohorts are shown in Fig. 1. Eligible participants were community-dwelling older adults aged 65 years and older. We excluded participants with cognitive impairment (a Short Portable



Mental Status Questionnaire score, SPMSQ < 8) [19], living in an institution, or incomplete frailty data in 2007. The study sample comprised 1283 community-dwelling adults aged 65 years or older at baseline (Fig. 1).

Measures

Frailty assessment

Frailty was assessed using the modified versions [20] of Fried's frailty phenotype [21], which includes five components: shrinking, weakness, exhaustion, slowness, and low physical activity. This modified frailty definition is extensively utilized and has already been validated [20, 22, 23]. Shrinking was considered a lack of appetite that occurred frequently or most of the time in the previous week. For those answering "not applicable" in poor appetite was scored as no shrinking. Weakness was defined as having any difficulty lifting or carrying something weighing 11–12 kg (like two packs of rice). For those answering "not know" in carrying was scored as positive weakness. Exhaustion was considered when subjects answered: "I could not get going" or "I felt everything I did was an effort" often (over 4 days) in the last week. For those answering "not applicable" or "not know" in these two items was scored as positive exhaustion. Individuals who had or were unable to walk 200–300 m were classified as slow. Individuals who did not engage in an outside

activity (e.g., walking, hiking, running, or gardening) at least once or twice per week were considered low activity. Frailty scores ranged from 0 to 5 on the five aforementioned items; a higher score indicates poorer frailty status. Respondents who fulfilled at least three of the five items were considered frail; those who met fewer than three criteria were considered non-frail.

Change in frailty status

Change in frailty status was calculated by subtracting the baseline score from the 4-year follow-up score, which was then classified into three categories: improvement (< 0), worsening (> 0), and stability (= 0).

Self-management behaviors

Participants were asked: "In the past year, have you used some measures in daily life to prevent or control chronic disease?" with six options 1) weight control, 2) quitting smoking or no smoking, 3) drinking less or no drinking, 4) taking regular exercise (≥ 3 times/week and 30 mins/time), 5) eating a healthy diet (a more balanced diet), 6) keeping a regular lifestyle, avoid sitting up for the night, reducing life stress, enough sleep, regular meals... etc. Participants who answered "yes" to the above item were considered positive for that self-management behavior. Changes in self-management behaviors between 2007

and 2011 were classified as 1) maintained no (no to no), 2) decreased (yes to no), increased (no to yes), and maintained yes (yes to yes). Not applicable in smoking or drinking less were considered as no smoking or drinking and classified into the “maintained yes” (yes-to-yes) group in these two behaviors.

Personal characteristics

Demographic data included age, gender, education level, marital status, area of residence, and chronic diseases. Age was categorized into two groups: 65–74 years and ≥ 75 years. Education level was classified into lower (illiteracy and elementary school) and higher (junior high school to senior high education and above). The area of residence was categorized into city + urban and rural. Chronic diseases were classified as “yes” and “no” for diabetes mellitus, heart disease, stroke, cancer, lung disease, renal disease, and muscular-skeletal diseases (joint arthritis, hip fracture, and osteoporosis).

Data analysis

Descriptive statistics for personal characteristics and self-management behaviors are presented as frequencies and percentages for categorical variables. The Chi-squared test was used to compare the distribution of personal characteristics and self-management behaviors between the groups with each frailty status. The association between changes in self-management behaviors and changes in frailty status after follow-up was examined using multinomial logistic regression analyses. The multivariate model included all significant covariates from the univariate analysis and the six self-management behaviors. Frailty stability (no changes in frailty score) and maintained no self-management behavior were set as the reference group in the outcome and independent variables, respectively. The relative risk ratio (RRR) was calculated. In addition, we further stratified the age group (65–74 years versus ≥ 75 years) to examine the moderation effect of age in the relationship between changes in self-management behavior and in frailty status. Data were processed using SPSS version 26.0 (IBM, Inc., Chicago, IL, USA). The significance level was set at $\alpha = 0.05$; all tests were two-tailed.

Results

The characteristics of the participants classified by frailty status are shown in Table 1. Almost half of the participants were ≥ 75 years old (46.8%), with a higher proportion of males (62.2%) than females (37.8%). Almost three-quarters (72.3%) of the participants were married, and more than half (60.8%) had only obtained a lower level of education. Of the 1283 respondents, 91.3% (1171) were classified as non-frail and 8.7% (112) as frail

at baseline. Older age, female sex, low educational attainment, and a history of heart disease, stroke, lung disease, renal disease, and muscular-skeletal disease were significantly associated with frailty at baseline.

During the 4-year follow-up, there were 196 (15.3%) deaths, and 191 (14.9%) participants became frail. Bivariate analysis showed that being over a 75-years-old and having chronic illnesses were associated with a higher risk of being frail (the participants who passed away were classified as frail), whereas being married was associated with a decreased risk of frailty after the 4-year follow-up (Table 1).

Regarding self-management behaviors, the majority of participants maintained a regular lifestyle (73.7%), performed diet control (68.4%), participated in regular exercise (67.5%), quit smoking or did not smoke (64.7%), and drank less or did not drink (64.5%) (Table 1). Participants who reported maintaining their body weight, exercising, performing diet control, and keeping a regular lifestyle had a lower risk of being frail at baseline and follow-up.

Table 2 shows the transitions of frailty status and self-management behaviors between baseline and after 4 years of follow-up. Overall, 514 (40.1%) participants maintained their frailty status, 424 (33.0%) worsened, and only 149 (11.6%) improved. For changes in self-management behaviors, most of those who maintained behaviors stayed frailty stability.

Table 3 presents multinomial logistic regression analyses of the self-management behaviors changes on the frailty status changes between 2007 and 2011, adjusted for personal characteristics and chronic disease. In Model 1 univariate analysis, compared to those who maintained no self-management behaviors, those who maintained (yes-to-yes) or increased their self-management behaviors (no-to-yes) in maintaining body weight, exercise, diet control, and regular lifestyle had a lower risk of frailty worsening rather than frailty stability. Participants who decreased exercise behaviors (yes-to-no) had a higher risk (RRR = 2.39) of frailty worsening, while maintaining frequent exercise (yes-to-yes) was associated with a lower ratio (RRR = 0.451) of improving their frailty status rather than remaining stable. Personal characteristics of those over 75 years, female sex, and a history of heart disease were significantly associated with a higher risk of frailty worsening (RRR = 1.429 ~ 1.689) over frailty stability. In addition, participants with heart disease and muscular-skeletal disease had a higher ratio of frailty improvement than over stability (RRR = 2.373 and 1.717, respectively) (Table 3, Model 1).

After controlling individual covariates and chronic diseases, the final multivariate multinomial logistic regression model (Table 3, Model 2 Multivariate) showed that

Table 1 Characteristics of participants on frailty in older adults (N = 1283)

Variables	2007		<i>p</i> ^a	2011			<i>p</i> ^a
	Non-frail	Frail		Non-frail	Frail	Death	
	<i>n</i> = 1171	<i>n</i> = 112		<i>n</i> = 896	<i>n</i> = 191	<i>n</i> = 196	
	N (%)	N (%)		N (%)	N (%)	N (%)	
Personal characteristics at baseline							
Age (year) in 2007							
65 – 74	649 (55.4)	34 (30.4)	<0.001	549 (61.3)	60 (31.4)	74 (37.8)	<0.001
≥ 75	522 (44.6)	78 (69.6)		347 (38.7)	131 (68.6)	122 (62.2)	
Gender							
Male	749 (64.0)	49 (43.8)	<0.001	555 (61.9)	95 (49.7)	148 (75.5)	0.774
Female	422 (36.0)	63 (56.3)		341 (38.1)	96 (50.3)	48 (24.5)	
Marital Status							
Divorced/Widowed/ Separated/Single	313 (26.8)	38 (33.9)	0.104	225 (25.1)	72 (37.7)	54 (27.6)	0.006
Married	857 (73.2)	74 (66.1)		670 (74.9)	119 (62.3)	142 (72.4)	
Educational level ^d							
Lower	699 (59.7)	81 (72.3)	0.009	538 (60.0)	126 (66.0)	116 (59.2)	0.402
Higher	472 (40.3)	31 (27.7)		358 (40.0)	65 (34.0)	80 (40.8)	
Area of residence							
City + Urban	806 (68.8)	74 (66.1)	0.548	607 (67.7)	135 (70.7)	138 (70.4)	0.322
Rural	365 (31.2)	38 (33.9)		289 (32.3)	56 (29.3)	58 (29.6)	
Diseases							
Diabetes mellitus	177 (15.1)	24 (21.4)	0.079	123 (13.7)	32 (16.8)	46 (23.5)	0.004
Heart disease	279 (23.8)	48 (42.9)	<0.001	199 (22.2)	70 (36.6)	58 (29.6)	<0.001
Stroke	45 (3.8)	19 (17.0)	<0.001	30 (3.3)	15 (7.9)	19 (9.7)	<0.001
Cancer	52 (4.4)	8 (7.1)	0.196	27 (3.0)	7 (3.7)	26 (13.3)	<0.001
Lung disease	144 (12.3)	24 (21.4)	0.006	92 (10.3)	33 (17.3)	43 (21.9)	<0.001
Renal disease	112 (9.6)	20 (17.9)	0.006	72 (8.0)	26 (13.6)	34 (17.3)	<0.001
Muscular skeletal disease ^e	366 (31.3)	62 (55.4)	<0.001	279 (31.2)	81 (42.4)	68 (34.7)	0.011
Self-management behaviours							
Maintain body weight	404 (34.5)	28 (25.0)	0.042	314 (35.0)	33 (17.3)	-	<0.001
Quit smoking or no smoking	654 (73.1) ^b	176 (45.4) ^b	<0.001	761 (84.9) ^b	168 (88.0) ^b	-	0.282
Drinking less or no drinking	651 (72.7) ^c	176 (45.4) ^c	<0.001	799 (89.2) ^c	180 (94.2) ^c	-	0.034
Exercise	838 (71.6)	28 (25.0)	<0.001	619 (69.1)	37 (19.4)	-	<0.001
Diet control	816 (69.7)	62 (55.4)	0.002	584 (65.2)	95 (49.7)	-	<0.001
Regular lifestyle	873 (74.6)	72 (64.3)	0.018	684 (76.3)	103 (53.9)	-	<0.001

^a Chi-square tests (two-tailed). In 2011, *p* value was calculated by coding "Death" as frail

^b Quit smoking, not applicable/no smoking was coded as "Yes" in 2007 and 2011

^c Drinking less, not applicable/no drinking was coded as "Yes" in 2007 and 2011

^d Educational level: Lower: illiterate + elementary school, higher: from junior high school to senior high education and above

^e Muscular skeletal disease includes joint arthritis, hip fractures, and osteoporosis

decreasing the exercise behaviors (yes-to-no) had a higher risk of worsening in frailty states (RRR = 2.726); maintaining frequent physical exercise (yes-to-yes) predicted a lower risk of worsening (RRR = 0.621) and a lower ratio of improving their frailty status (RRR = 0.542) rather than remaining stable. Participants who maintained body weight (yes-to-yes) had a lower risk of worsening by 58.3% (RRR = 0.417) and a lower ratio of frailty improvement (RRR = 0.493) rather than remaining stable. However, there were no associations between the behavioral transitions of smoking, drinking, diet control, or regular lifestyle on the frailty status changes. Therefore, people who maintained body weight and frequent

physical exercise were associated with a higher ratio of frailty stability compared to those who maintained no behaviors. Being aged ≥ 75 years old remained a prognostic factor for frailty worsening. In addition, a history of heart disease also predicted frailty stability.

Additionally, the moderation analysis stratified by age groups is also shown in Table 3. Age was a moderator between changes in self-management behaviors and in frailty status. In participants 65–74 years old, the risk of maintaining body weight and frequent physical exercise on the frailty worsening were almost similar to the phenomenon of the whole older adults. However, ex-smokers or no smokers had a higher risk of frailty worsening

Table 2 Transitions of frailty status and self-management behaviors between baseline and follow-up

	2011, Changes in Frailty status				
	Stability, n (%)	Improvement, n (%)	Worsening, n (%)	Death, n (%)	Total
Frailty status in 2007					
Non-frail	486 (41.5)	119 (10.2)	407 (34.7)	159 (13.6)	1171
Frail	28 (25.0)	30 (26.8)	17 (15.2)	37 (33.0)	112
Total	514 (40.1)	149 (11.6)	424 (33.0)	196 (15.3)	1283
Self-management Behaviors between 2007 and 2011					
Maintain body weight					
Maintained No	224 (32.7)	78 (11.4)	240 (35.1)	142 (20.8)	684
Decreased (Yes to No)	89 (44.9)	30 (15.2)	79 (39.9)	—	198
Increased (No to Yes)	84 (50.3)	24 (14.4)	59 (35.3)	—	167
Maintained Yes	117 (50.0)	17 (7.3)	46 (19.6)	54 (23.1)	234
Quit smoking or no smoking					
Maintained No	64 (22.6)	17 (6.0)	44 (15.6)	158 (55.8)	283
Decreased (Yes to No)	16 (48.5)	1 (3.0)	16 (48.5)	—	33
Increased (No to Yes)	80 (47.1)	21 (12.3)	69 (40.6)	—	170
Maintained Yes	354 (44.4)	110 (13.8)	295 (37.0)	38 (4.8)	797
Less drinking or no drinking					
Maintained No	48 (18.7)	8 (3.1)	34 (13.2)	167 (65.0)	257
Decreased (Yes to No)	12 (66.7)	3 (16.7)	3 (16.6)	—	18
Increased (No to Yes)	105 (52.8)	31 (15.6)	63 (31.6)	—	199
Maintained Yes	349 (43.1)	107 (13.2)	324 (40.1)	29 (3.6)	809
Exercise					
Maintained No	88 (30.1)	37 (12.7)	91 (31.2)	76 (26.0)	292
Decreased (Yes to No)	57 (26.5)	17 (7.9)	141 (65.6)	—	215
Increased (No to Yes)	58 (46.4)	36 (28.8)	31 (24.8)	—	125
Maintained Yes	311 (47.8)	59 (9.1)	161 (24.7)	120 (18.4)	651
Diet control					
Maintained No	75 (29.5)	24 (9.5)	78 (30.7)	77 (30.3)	254
Decreased (Yes to No)	99 (42.9)	25 (10.8)	107 (46.3)	—	231
Increased (No to Yes)	68 (45.0)	33 (21.9)	50 (33.1)	—	151
Maintained Yes	272 (42.0)	67 (10.4)	189 (29.2)	119 (18.4)	647
Regular life					
Maintained No	43 (26.9)	16 (10.0)	47 (29.4)	54 (33.7)	160
Decreased (Yes to No)	80 (41.2)	19 (9.8)	95 (49.0)	—	194
Increased (No to Yes)	89 (50.0)	39 (21.9)	50 (28.1)	—	178
Maintained Yes	302 (40.2)	75 (10.0)	232 (30.9)	142 (18.9)	751

(RRR=2.437) than stable frailty in the younger old. Adversely, maintaining body weight or quitting smoking behaviors were less likely associated with frailty worsening in people over 75 years. Among individuals over 75 years old, exercise was the only factor affecting their frailty status. Compared to no exerciser, older old who decreased their physical exercise was associated with a higher risk of frailty worsening (RRR=3.255) as the younger old did. Furthermore, older old with increased frequent physical exercise (no-to-yes) was significantly associated with an improvement in frailty status (RRR=3.684), which was not significant in the younger old and the whole groups.

Discussion

This study used national data to describe the changes in frailty status among community-dwelling older adults in Taiwan and investigate the changes in self-management behaviors on the changes in frailty status over 4 years. The prevalence of frailty was 8.7% at baseline and 14.9% after 4 years of follow-up; 15.3% of participants died during follow-up. The prevalence of frailty in our study was similar to reports from Japan (8.7%) [24] and a rural setting in China (8.7%) [25] but slightly higher than analyses conducted in Hong Kong (6.3%) [26], Korea (7.8%) [27], and lower than data from the US (15.3%) [28], European countries (12%) [29], and the estimated global prevalence

Table 3 Changes of self-management behaviors on changes in frailty status with age stratification by multinomial logistic regression (N = 1087)

Changes of Self-management behaviors	Model 1 Univariate (Reference: Stability)				Model 2 Multivariate (Reference: Stability)			
	Improvement		Worsening		Improvement		Worsening	
	RRR (95% CI)	p	RRR (95% CI)	p	RRR (95% CI)	p	RRR (95% CI)	p
Total Sample (N = 1087)								
Maintain body weight	-	-	-	-	-	-	-	-
Maintained No (ref.)	-	-	-	-	-	-	-	-
Decreased (Yes to No)	0.968 (0.595, 1.576)	0.896	0.828 (0.582, 1.180)	0.297	1.207 (0.705, 2.065)	0.493	0.781 (0.525, 1.162)	0.223
Increased (No to Yes)	0.821 (0.487, 1.383)	0.457	0.656 (0.449, 0.958)	0.029	0.772 (0.433, 1.379)	0.382	0.762 (0.496, 1.170)	0.214
Maintained Yes	0.417 (0.236, 0.738)	0.003	0.367 (0.249, 0.540)	<0.001	0.493 (0.258, 0.941)	0.032	0.417 (0.264, 0.656)	<0.001
Quit smoking or no smoking	-	-	-	-	-	-	-	-
Maintained No (ref.)	-	-	-	-	-	-	-	-
Decreased (Yes to No)	0.235 (0.029, 1.902)	0.175	1.455 (0.659, 3.212)	0.354	0.320 (0.039, 2.657)	0.291	1.707 (0.730, 3.992)	0.218
Increased (No to Yes)	0.988 (0.482, 2.028)	0.974	1.255 (0.760, 2.071)	0.375	0.955 (0.430, 2.125)	0.911	1.729 (0.977, 3.059)	0.060
Maintained Yes	1.170 (0.658, 2.081)	0.594	1.212 (0.801, 1.833)	0.362	1.065 (0.542, 2.093)	0.856	1.040 (0.630, 1.715)	0.878
Drinking less or no drinking	-	-	-	-	-	-	-	-
Maintained No (ref.)	-	-	-	-	-	-	-	-
Decreased (Yes to No)	1.500 (0.345, 6.524)	0.589	0.353 (0.092, 1.347)	0.127	1.863 (0.401, 8.664)	0.427	0.409 (0.100, 1.675)	0.214
Increased (No to Yes)	1.771 (0.758, 4.140)	0.187	0.847 (0.494, 1.452)	0.546	1.664 (0.658, 4.206)	0.282	0.910 (0.490, 1.689)	0.765
Maintained Yes	1.840 (0.844, 4.010)	0.125	1.311 (0.824, 2.086)	0.254	1.594 (0.687, 3.697)	0.278	1.350 (0.793, 2.299)	0.269
Exercise	-	-	-	-	-	-	-	-
Maintained No (ref.)	-	-	-	-	-	-	-	-
Decreased (Yes to No)	0.709 (0.365, 1.378)	0.311	2.392 (1.564, 3.658)	<0.001	0.800 (0.400, 1.599)	0.528	2.726 (1.729, 4.296)	<0.001
Increased (No to Yes)	1.476 (0.838, 2.600)	0.177	0.517 (0.306, 0.874)	0.014	1.389 (0.756, 2.551)	0.290	0.613 (0.353, 1.067)	0.083
Maintained Yes	0.451 (0.281, 0.725)	0.001	0.501 (0.353, 0.710)	<0.001	0.542 (0.318, 0.925)	0.025	0.621 (0.416, 0.928)	0.020
Diet control	-	-	-	-	-	-	-	-
Maintained No (ref.)	-	-	-	-	-	-	-	-
Decreased (Yes to No)	0.780 (0.418, 1.490)	0.465	1.039 (0.684, 1.579)	0.857	0.855 (0.426, 1.717)	0.660	0.798 (0.492, 1.295)	0.362
Increased (No to Yes)	1.517 (0.816, 2.819)	0.188	0.707 (0.436, 1.147)	0.160	1.348 (0.678, 2.681)	0.394	0.887 (0.516, 1.525)	0.664
Maintained Yes	0.770 (0.452, 1.310)	0.335	0.668 (0.463, 0.965)	0.031	1.065 (0.551, 2.058)	0.853	0.882 (0.550, 1.415)	0.602
Regular lifestyle	-	-	-	-	-	-	-	-
Maintained No (ref.)	-	-	-	-	-	-	-	-
Decreased (Yes to No)	0.638 (0.298, 1.367)	0.248	1.086 (0.653, 1.808)	0.750	0.725 (0.319, 1.644)	0.441	1.124 (0.632, 2.000)	0.690
Increased (No to Yes)	1.178 (0.593, 2.339)	0.641	0.514 (0.300, 0.882)	0.016	1.232 (0.578, 2.625)	0.589	0.705 (0.386, 1.288)	0.255
Maintained Yes	0.667 (0.356, 1.250)	0.206	0.703 (0.449, 1.100)	0.123	0.966 (0.459, 2.029)	0.926	1.105 (0.634, 1.926)	0.725
Personal characteristics	-	-	-	-	-	-	-	-
≥ 75 years of age	1.137 (0.785, 1.648)	0.497	1.689 (1.302, 2.191)	<0.001	1.066 (0.719, 1.581)	0.749	1.575 (1.187, 2.088)	0.002
Female	1.388 (0.958, 2.010)	0.083	1.429 (1.098, 1.859)	0.008	1.070 (0.676, 1.693)	0.774	1.396 (0.995, 1.960)	0.053
Married	0.923 (0.610, 1.395)	0.702	0.789 (0.592, 1.052)	0.107	-	-	-	-
Higher education level	0.865 (0.594, 1.258)	0.448	0.836 (0.642, 1.089)	0.184	-	-	-	-
Chronic diseases	-	-	-	-	-	-	-	-
Diabetes mellitus	0.937 (0.550, 1.595)	0.809	1.035 (0.718, 1.492)	0.855	-	-	-	-
Heart disease	2.373 (1.588, 3.546)	<0.001	1.677 (1.235, 2.278)	0.001	2.242 (1.460, 3.443)	<0.001	1.617 (1.156, 2.261)	0.005
Stroke	1.766 (0.741, 4.211)	0.200	1.622 (0.835, 3.149)	0.153	-	-	-	-
Cancer	0.601 (0.174, 2.078)	0.421	0.998 (0.486, 2.050)	0.996	-	-	-	-
Lung disease	1.439 (0.827, 2.504)	0.198	1.383 (0.921, 2.077)	0.118	-	-	-	-
Renal disease	1.388 (0.755, 2.552)	0.291	1.235 (0.785, 1.943)	0.362	-	-	-	-
Muscular skeletal disease	1.717 (1.180, 2.499)	0.005	1.087 (0.825, 1.433)	0.553	1.496 (0.993, 2.255)	0.054	0.854 (0.624, 1.168)	0.323
Among individuals 65–74 years old (N = 609)								
Maintain body weight	-	-	-	-	-	-	-	-
Maintained No (ref.)	-	-	-	-	-	-	-	-
Decreased (Yes to No)	0.912 (0.480, 1.736)	0.780	0.798 (0.490, 1.298)	0.364	1.149 (0.556, 2.374)	0.708	0.742 (0.423, 1.302)	0.299
Increased (No to Yes)	0.711 (0.361, 1.399)	0.324	0.576 (0.345, 0.964)	0.036	0.743 (0.350, 1.578)	0.440	0.616 (0.341, 1.111)	0.107
Maintained Yes	0.396 (0.193, 0.811)	0.011	0.338 (0.201, 0.570)	<0.001	0.462 (0.199, 1.074)	0.073	0.327 (0.174, 0.614)	0.001
Quit smoking or no smoking	-	-	-	-	-	-	-	-
Maintained No (ref.)	-	-	-	-	-	-	-	-
Decreased (Yes to No)	1.68 × 10 ⁴ (1.68 × 10 ⁴ , 1.68 × 10 ⁴)	-	1.818 (0.618, 5.352)	0.278	2.29 × 10 ⁴ (2.29 × 10 ⁴ , 2.29 × 10 ⁴)	-	2.422 (0.724, 8.103)	0.151
Increased (No to Yes)	1.110 (0.479, 2.812)	0.742	1.596 (0.762, 3.341)	0.215	1.330 (0.489, 3.619)	0.577	2.437 (1.043, 5.698)	0.040
Maintained Yes	1.018 (0.493, 2.101)	0.963	1.743 (0.942, 3.226)	0.077	0.871 (0.360, 2.110)	0.760	1.524 (0.714, 3.253)	0.277
Drinking less or no drinking	-	-	-	-	-	-	-	-
Maintained No (ref.)	-	-	-	-	-	-	-	-
Decreased (Yes to No)	0.889 (0.156, 5.073)	0.895	0.491 (0.117, 2.054)	0.330	1.314 (0.203, 8.492)	0.774	0.515 (0.110, 2.414)	0.400
Increased (No to Yes)	1.108 (0.416, 2.949)	0.838	0.680 (0.329, 1.405)	0.298	1.013 (0.334, 3.073)	0.982	0.738 (0.318, 1.713)	0.480
Maintained Yes	1.121 (0.467, 2.694)	0.798	1.061 (0.571, 1.968)	0.852	1.040 (0.390, 2.775)	0.938	0.969 (0.472, 1.988)	0.932
Exercise	-	-	-	-	-	-	-	-
Maintained No (ref.)	-	-	-	-	-	-	-	-
Decreased (Yes to No)	0.641 (0.285, 1.438)	0.280	2.210 (1.242, 3.933)	0.007	0.676 (0.287, 1.592)	0.371	2.518 (1.346, 4.711)	0.004
Increased (No to Yes)	0.907 (0.445, 1.852)	0.789	0.408 (0.199, 0.837)	0.015	0.846 (0.393, 1.820)	0.668	0.466 (0.217, 1.000)	0.050
Maintained Yes	0.263 (0.142, 0.487)	<0.001	0.434 (0.268, 0.704)	0.001	0.300 (0.149, 0.602)	0.001	0.572 (0.328, 1.000)	0.050
Diet control	-	-	-	-	-	-	-	-
Maintained No (ref.)	-	-	-	-	-	-	-	-
Decreased (Yes to No)	0.696 (0.301, 1.613)	0.399	0.994 (0.556, 1.776)	0.983	0.811 (0.318, 2.067)	0.661	0.812 (0.409, 1.612)	0.551
Increased (No to Yes)	1.143 (0.503, 2.596)	0.750	0.648 (0.333, 1.264)	0.203	1.065 (0.428, 2.645)	0.893	0.802 (0.376, 1.710)	0.568
Maintained Yes	0.746 (0.380, 1.462)	0.393	0.671 (0.408, 1.104)	0.116	1.266 (0.534, 3.001)	0.593	0.964 (0.496, 1.873)	0.915
Regular lifestyle	-	-	-	-	-	-	-	-
Maintained No (ref.)	-	-	-	-	-	-	-	-
Decreased (Yes to No)	0.781 (0.298, 2.051)	0.616	0.989 (0.501, 1.952)	0.974	0.960 (0.331, 2.783)	0.939	1.088 (0.493, 2.400)	0.834
Increased (No to Yes)	1.006 (0.424, 2.390)	0.989	0.438 (0.219, 0.876)	0.020	1.325 (0.507, 3.459)	0.566	0.674 (0.305, 1.491)	0.330
Maintained Yes	0.650 (0.293, 1.441)	0.289	0.636 (0.356, 1.135)	0.126	1.116 (0.430, 2.895)	0.822	1.058 (0.506, 2.212)	0.882
Personal characteristics	-	-	-	-	-	-	-	-
Female	1.529 (0.946, 2.472)	0.083	2.019 (1.412, 2.886)	<0.001	1.492 (0.776, 2.867)	0.230	1.799 (1.100, 2.945)	0.019
Married	0.917 (0.509, 1.653)	0.773	0.766 (0.501, 1.173)	0.220	-	-	-	-
Higher education level	0.815 (0.496, 1.339)	0.419	0.550 (0.375, 0.808)	0.002	1.081 (0.619, 1.889)	0.784	0.725 (0.466, 1.128)	0.154
Chronic diseases	-	-	-	-	-	-	-	-
Diabetes mellitus	1.288 (0.678, 2.445)	0.439	1.054 (0.638, 1.740)	0.838	-	-	-	-
Heart disease	2.338 (1.357, 4.029)	0.002	1.755 (1.136, 2.709)	0.011	2.032 (1.127, 3.663)	0.018	1.713 (1.057, 2.777)	0.029
Stroke	2.602 (0.833, 8.700)	0.098	2.252 (0.843, 6.015)	0.105	-	-	-	-
Cancer	0.356 (0.045, 2.818)	0.328	1.076 (0.403, 2.874)	0.883	-	-	-	-
Lung disease	2.262 (1.033, 4.956)	0.041	1.965 (1.041, 3.707)	0.037	1.923 (0.825, 4.482)	0.130	1.847 (0.917, 3.719)	0.086
Renal disease	1.343 (0.602, 2.995)	0.471	1.681 (0.942, 3.002)	0.079	-	-	-	-
Muscular skeletal disease	1.887 (1.156, 3.083)	0.011	1.313 (0.899, 1.917)	0.159	1.591 (0.917, 2.760)	0.099	0.953 (0.614, 1.478)	0.828
Among individuals over 75 years old (N = 478)								
Maintain body weight	-	-	-	-	-	-	-	-
Maintained No (ref.)	-	-	-	-	-	-	-	-
Decreased (Yes to No)	1.051 (0.498, 2.218)	0.897	0.875 (0.520, 1.472)	0.614	1.168 (0.500, 2.727)	0.720	0.778 (0.437, 1.386)	0.394
Increased (No to Yes)	1.039 (0.456, 2.367)	0.927	0.823 (0.461, 1.469)	0.510	0.766 (0.297, 1.977)	0.581	0.951 (0.494, 1.828)	0.879
Maintained Yes	0.459 (0.178, 1.185)	0.108	0.445 (0.247, 0.247)	0.007	0.543 (0.184, 1.601)	0.269	0.552 (0.278, 1.097)	0.090
Quit smoking or no smoking	-	-	-	-	-	-	-	-
Maintained No (ref.)	-	-	-	-	-	-	-	-
Decreased (Yes to No)	0.800 (0.078, 8.189)	0.851	1.371 (0.306, 4.755)	0.619	1.366 (0.121, 15.373)	0.801	1.385 (0.373, 5.138)	0.627
Increased (No to Yes)	0.727 (0.209, 2.533)	0.617	1.013 (0.495, 2.072)	0.972	0.511 (0.128, 2.042)	0.342	1.182 (0.526, 2.656)	0.686
Maintained Yes	1.441 (0.556, 3.735)	0.452	0.901 (0.498, 1.632)	0.731	1.113 (0.388, 3.193)	0.843	0.697 (0.354, 1.372)	0.296
Drinking less or no drinking	-	-	-	-	-	-	-	-
Maintained No (ref.)	-	-	-	-	-	-	-	-
Decreased (Yes to No)	6.667 (0.323, 137.403)	0.219	2.95 × 10 ⁴ (2.95 × 10 ⁴ , 2.95 × 10 ⁴)	-	10.079 (0.401, 253.247)	0.160	4.61 × 10 ⁴ (4.61 × 10 ⁴ , 4.61 × 10 ⁴)	-
Increased (No to Yes)	6.500 (0.793, 53.271)	0.081	1.100 (0.488, 2.480)	0.818	7.945 (0.362, 73.186)	0.067	1.365 (0.528, 3.532)	0.521
Maintained Yes	6.963 (0.909, 53.315)	0.062	1.679 (0.828, 3.403)	0.151	5.582 (0.662, 47.040)	0.114	2.287 (0.990, 5.283)	0.053
Exercise	-	-	-	-	-	-	-	-
Maintained No (ref.)	-	-	-	-	-	-	-	-
Decreased (Yes to No)	0.848 (0.258, 28							

of frailty (10.7%) [30]. The wide range in the reported prevalence of frailty across these studies may be due to differences in the characteristics of the populations (races, geographical area) and the effect of phenotypic components [30, 31]. However, overall, the prevalence of frailty at baseline in this study is compatible with the rates for other countries.

We examined the changes in frailty status after 4 years of follow-up among community-dwelling older adults. The majority of participants maintained their frailty status (40.1%) (Table 2). In addition, frailty state improvement (11.6%) was higher than previous estimates in Israel (2.1%) [6], Ireland (6%) [32], Italy (8.2%) [12], U.S (8.3%) [33], and China (9.2%) [34], but lower than that reports in Germany (14%) [7], Indonesia (14.8%) [35], 15.1% in Spain [36], Hong Kong (17.9%) [37], Japan (18%) [15], and Malaysia (22.9%) [38]. Transitions to greater frailty are more common than transitions to lesser frailty [5, 10, 33, 39], as we found in this study. The proportion of frailty transition in our study was comparable to a recent meta-analysis study, which revealed that over a mean of 3.9 years, half or more of older adults stayed in the same frailty status, roughly 10% improved, and nearly 40% worsened [8]. Furthermore, our data revealed that the majority of non-frail subjects maintained their status after 4 years of follow-up, which was consistent with previous research in other populations [12, 15, 32, 37, 40]. The wide variations in the follow-up period for each cohort, differences in the regions of study, national income levels, frailty measurements, and the inclusion of mortalities may limit comparisons of the rates of frailty transitions across different studies [8, 41]. Previous studies only assessed the effects of risk factors such as older age and diseases on the reversal of frailty [42]. Thus, the effects of modifiable factors associated with frailty improvement were poorly explored.

Individuals with healthy behavioral habits such as body weight maintenance, exercise, diet control, and regular lifestyle had a lower risk of being frail in our univariate multinomial logistic regression model. The final multinomial logistic regression model revealed that participants aged 65 to 74 who decreased exercise behaviors had a higher risk (2.518) of worsening transition. In contrast, those who maintained regular exercise had a lower risk of frailty worsening as well as a lower ratio of improving their frailty status rather than remaining stable in the latter year after adjusting for personal and disease covariates (Table 3, Model 2). Moreover, maintaining appropriate body weight was also associated with a lower risk of worsening their frailty status rather than remaining stable after adjusting for personal and disease covariates (Table 3, Model 2). These results suggested that among the younger old group, exercise and

maintaining appropriate body weight might significantly stabilize frailty status compared to those who maintained no behaviors. Adversely, maintaining body weight was less likely associated with the change in frailty status in people over 75 years. However, increasing physical exercise was associated with a higher ratio (3.684) of improvement in frailty status, and decreasing exercise behavior had a higher risk of frailty worsening (3.255) than stable frailty among the older old group. Currently, exercise with nutrition-based therapies has provided the most evidence for delaying frailty worsening [43]. Our finding was in line with previous studies, which highlighted that low levels of physical exercise elevated the probability of worsening transition [12, 38]. In comparison, performing more regular physical activity reduced probability of frailty worsening [10, 11, 44] and a greater likelihood of frailty improvement [10, 44]. Our results indicate that it is beneficial to encourage seniors aged 65–74 to maintain regular exercise with any type of exercise that may potentially increase the likelihood of frailty state stability and improve their status even aged 75 years and over. Do not give up on exercise, and never start too late. Individualized exercise programs tailored to frailty status and other chronic diseases are necessary to reduce the progression of frailty and prevent adverse outcomes.

Besides, this study also found that maintaining appropriate body weight was associated with a higher ratio of frailty stability among younger old aged 65–74 years after adjusting for personal and disease covariates (Table 3, Model 2), not overweight or underweight. Abdominal obesity has been proven to be associated with greater frailty [35, 45] and mortality [12]. A higher body mass index (BMI) was associated with new-onset frailty [15, 46] and a higher risk of frailty worsening [12]. Increasing BMI also hampered recovering robustness [36, 47]. Excessive weight gain is a major risk factor for metabolic syndrome, negatively affecting cardiovascular systems [48]. In contrast to obesity, being underweight was less likely to worsen frailty but associated with a higher risk of mortality [12]. It is critical to maintain a healthy body weight to avoid frailty status in younger old aged 65–74 years.

In addition, this study found that ex-smokers or never-smokers were associated with a higher risk of frailty worsening in the younger old group, but not in the older old group. This result was different from the study of Pollock et al. [33], that use of tobacco products, either in the past or currently, was a predictor of the progression of frailty [33]. Smoke is a contradictory factor in health, such as cognitive improvement [49]. This cognitive improvement effect of tobacco use may affect younger elders' frailty status. Further studies are recommended to explore the association between smoking behavior and

frailty transition in community-dwelling older adults. The results of multivariate models in this study showed that the behavioral transitions of drinking, diet control, or regular lifestyle were not associated with the changes in frailty status after adjusting covariates. Maintaining body weight and exercise could potentially lessen the likelihood of frailty progression for the younger old, and exercise was the only factor to improve their frailty status in the older old group.

We found that participants aged 75 years or above had an increased risk of frailty worsening (Tables 1 & 3). Previous studies also found that older age increased the risk of frailty worsening [12, 37], and younger age was associated with a higher probability of frailty improvement [37, 42]. As people get older, they gradually undergo age-related degeneration that leads to decreased functional capacity and physiological reserves, making individuals more vulnerable to adverse health outcomes [21, 50]. Thus, it is essential to develop strategies to prevent frailty in high-risk older age groups. The present study found that maintaining body weight, quitting smoking, and exercising are frailty protectors for younger old adults, but only exercise is the protector for older old adults. Age was a moderator in the relationship between the transitions of maintaining body weight and frailty status. We should consider age as a crucial factor when developing the intervention to prevent the progression of frailty and maintain non-frail status in different age groups.

In this study, females were at a higher risk of frailty at baseline (Table 1), which was consistent with other studies [9, 30, 51]; moreover, being female remained a risk factor for change in frailty state in young old aged 65–74, but not in older old over 75 years (Table 3). Compared to men of the same age, women were more likely to be frail due to poorer grip strength, lower average amounts of lean body mass and muscle strength, and increased prevalence of sarcopenia during the aging process [21]. The more steady and progressive decline in females could lead to a higher increase in vulnerability to frailty in women than in males. Men were previously reported to be significantly more likely to maintain non-frail status, while women tend to develop prefrailty [8, 39]. Nevertheless, a recent population-based cohort study of older persons aged 70 and older in Germany indicated that men worsened more frequently than women [7]. Our finding showed that the female gender was the significant prognostic factor for frailty worsening in younger old below 75 years. Lower mortality and higher frailty may lead to a prolonged life span, though with a lower quality of life among females. However, there is no gender difference among older old over 75 years.

Besides, individuals with chronic illnesses including heart disease, stroke, lung disease, and renal disease at

baseline were at higher risk of frailty (Table 1), and heart disease remained a factor for the change in frailty status (Table 3, Model 2). These results are consistent with previous studies, which reported that a higher number of comorbidities were significantly associated with frailty [12, 28, 37]. However, in the younger old group, heart disease was associated with a higher ratio of frailty improvement ($RRR=2.032$) as well as worsening ($RRR=1.713$) rather than remaining stable (Table 3, Model 2). This may indicate that frailty status in patients aged 65–74 with heart disease can be improved or worsened depending on the other factors. The high prevalence of frailty in high-risk populations poses a public health challenge, and efficient strategies must be developed to prevent and reduce the disease burden.

This study was a prospective longitudinal cohort survey of a nationally representative sample. The large sample size and high follow-up rates enabled an accurate estimation of the changes in frailty status after 4 years of follow-up, which could enhance the generalizability of these results among community-dwelling older adults in Taiwan. Notably, this study took into account the changes in self-management behaviors at the baseline and 4 years afterward, using multinomial logistic regression analysis to give a more holistic advice. The current study also explored the moderation effect of age between transitions of self-management behaviors and frailty status and revealed that the beneficial effect of self-management behaviors on changes in frailty status is different among younger old and older old adults. Cognitively impaired individuals ($SPMSQ < 8$) were excluded to avoid bias due to misreported information. As this cohort of seniors was followed up for 4 years, high attrition rates due to death and missing data were unavoidable. Moreover, this study utilized a secondary database to identify frailty using self-reported measures. This approach may lead to recall bias and misclassification and produce higher frailty estimates than performance-based measures [52]. Self-management behaviors were evaluated using simple questions that are straightforward but less precise than standardized measures, which may lead to under- or overestimation of the actual relationships between self-management behaviors and frailty. We used the Fried frailty phenotype, which may represent a lower prevalence of frailty than other broader phenotypes [30]. Notwithstanding, the Fried frailty phenotype is the most extensively validated scale and has been adopted for various epidemiological cohorts, which could enable comparisons between studies [53]. Finally, because of the study's design, we do not have frailty information during the period of baseline to follow-up. It is possible that older persons who became frail at the beginning of the study (first 12–24 months) may reduce their physical activity due to frailty. Such a

reverse association between exercise and frailty cannot be excluded in this study. Future research to make a more frequent assessment in a yearly manner may ameliorate this limitation.

Conclusions

This study used national data to investigate the changes in frailty status after a 4-year follow-up among Taiwanese community-dwelling older adults. The prevalence of frailty was 8.7% at baseline and 14.9% after 4 years of follow-up, with 196 (15.3%) deaths. Overall, the majority of the participants maintained or worsened their frailty status; only 11 % of them had improved. For younger old aged 65–74 years who maintained their body weight and kept frequent physical exercise are associated with a higher ratio of frailty stability after controlling for individual covariates and chronic diseases. Among older adults aged 75 years and over, increasing exercise behavior is the only factor to improve their frailty status. There were no associations between the behavioral transitions of smoking, drinking, diet control, or regular lifestyle on the frailty status changes. Older adults should be encouraged to perform adequate physical exercise and maintain a healthy body weight to maintain frailty stability in younger old aged 65–74 years, and especially perform more frequent exercise to improve frailty status in older old over 75 years. Health providers and policymakers should provide insights to help the elderly and caregivers to understand the importance of maintaining body weight and frequent exercise in older adults.

Abbreviations

TLSA: Taiwan Longitudinal Study in Aging; SPMSQ: Short Portable Mental Status Questionnaire; RRR: Relative Risk Ratio; CI: confidence interval.

Acknowledgements

We thank the participants and staff in the TLSA for their cooperation and assistance. Special thanks to Dr. Chi-Rong Li for his consultation in data analysis.

Authors' contributions

T-L. To. Planned the study, performed the data analysis, and wrote the paper. C-P. Kuo. Planned the study, supervised the data analysis, and contributed to revising the paper. C-J. Yeh. Supervised the data analysis and contributed to revising the paper. W-C. Liao. Planned the study, supervised the data analysis, and revised the manuscript. M-C. Lee. Planned the study, supervised the data analysis, and contributed to revising the paper. All authors read and approved the final manuscript.

Funding

The authors have no support or funding to report.

Availability of data and materials

The datasets used and analyzed during the current study are not publicly available but are available from the Health Promotion Administration at Ministry of Health and Welfare in Taiwan in <https://www.hpa.gov.tw/EngPages/Detail.aspx?nodeid=1077&pid=6197> on request with the permission of the Ministry of Health and Welfare, Taiwan.

Declarations

Ethics approval and consent to participate

The Population and Health Research Center of the Bureau of Health Promotion in Taiwan was responsible for this longitudinal survey. All personally identifiable information in TLSA is encrypted for patient protection. The TLSA study followed the ethical guidelines given in the declaration of Helsinki and was approved by the regional ethical review board in Taiwan (No.:BHP-960800522). Informed consent was obtained from all subjects and/or their legal guardian(s) included in the study.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Received: 15 December 2021 Accepted: 17 October 2022

Published online: 18 November 2022

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