Association of regular leisure-time physical activity with self-reported body mass index and obesity risk among middle-aged and older adults in Taiwan

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Research

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Abstract

Background

Through this study, we aimed to determine the association of regular leisure-time physical activity (LTPA) with self-reported body mass index (BMI) and obesity risk among middle-aged and older adults in Taiwan.

Methods

We conducted a cross-sectional study and reviewed the data derived from the Taiwan's National Physical Activity Survey (TNPAS). Responses from 12,687 participants aged 45–108 years from the database were collected in this study. All participants completed a standardized, structured questionnaire that solicited information regarding their demographic characteristics (age, gender, education, occupation, and self-reported health status), physical activity behaviors (regular/nonregular LTPA), and self-reported anthropometrics (height, weight, and BMI). Multiple linear and logistic regression were used to examine the association between regular LTPA and BMI as well as between regular LTPA and obesity status, respectively.

Results

Regular LTPA was associated with a male preponderance, normal weight, excellent or good self-reported health status, and a lower rate of underweight compared with nonregular LTPA. Regular LTPA was significant negatively associated with underweight (OR = 0.71, $p < 0.05$), whereas it had no significant relationship with BMI and obesity ($p > 0.05$).

Conclusions

Regular LTPA was associated with a reduced risk of underweight among middle-aged and elderly adults in Taiwan. Further research on the relevant mechanism underlying this phenomenon is warranted.

Background

According to the World Health Organization (WHO), the global prevalence of obesity nearly tripled since 1975, and approximately 13% (over 650 million) of adults worldwide were classified as obese in 2016 [1]. Obesity is defined as a body mass index (BMI) greater than or equal to 30 kg/m^2 , and it may increase the risk of developing coronary heart disease, hypertension, type 2 diabetes, sleep apnea, osteoarthritis, and some cancers [2]. However, Gurrìci *et al.* suggested that the cut-off point for obesity based on BMI in

Asian individuals should be 27 kg/m^2 , as Asian individuals with the same age, gender, and body fat percentage have an approximately 3 kg/m^2 lower BMI compared with Caucasian individuals [3].

Physical activity (PA) is recommended as an important part of weight management for enhancing weight loss and preventing weight regain [4]. Moreover, PA is associated with a decreased risk of cardiovascular disease (CVD), stroke, diabetes, metabolic syndrome, and cancers (e.g., colon and breast cancers) [4, 5]. The American College of Sports Medicine (ACSM) recommends that adults with overweight or obesity should perform moderate-intensity PA for ≥ 150 minutes/week to improve their health, and a progressive increase to 200–300 minutes/week was recommended for long-term weight loss [6]. However, 31% of adults (especially older adults) worldwide are physically inactive, leading to approximately 3 million deaths per year and costing global healthcare systems approximately US\$50 [7, 8].

According to the WHO, the terms “aging society” and “aged society” refer to societies with $\geq 7\%$ and $\geq 14\%$ of individuals aged ≥ 65 years, respectively [9]. Taiwan was considered an aging society in 1993 and became an aged society in 2018 [10]. It is estimated that in 2026, Taiwan will enter the era of a “super-aged society,” where the proportion of elderly adults would be $\geq 20\%$ [11]. Therefore, successful aging is an important issue in Taiwan for individuals to reduce the risk of chronic disease and disability, maintain physical and cognitive function, and sustain active engagement with life [12].

Numerous studies have found that older adults who participated in leisure-time physical activity (LTPA) had a reduced risk of many chronic diseases and increased physical and cognitive function as well as improved quality of life [13, 14]. However, relatively limited information is available regarding the relationship between LTPA and body mass index (BMI) and obesity risk with consideration for the health status, education, and occupation factors of middle-aged and elderly adults in Taiwan. Therefore, through the present study, we aimed to investigate the association of regular LTPA with self-reported BMI and obesity risk and the determining factors that influence this relationship among middle-aged and older adults in Taiwan.

Methods

Study design and participants

We performed a cross-sectional observational study using nationally representative data regarding middle-aged and older adults (age range, 45–108 years) from the Taiwan’s National Physical Activity Survey (TNPAS) conducted by the Taiwan’s Sports Administration, Ministry of Education. Recruitment was conducted through random-digit dialing of the numbers of the proportionally stratified sample by age, gender, and geographical districts; the detailed procedure has been described elsewhere (Ku *et al.*, 2006). The participants were citizens aged over 13 years and stratified by 22 cities/counties across Taiwan. The sample size of each city/county was calculated by its proportion to Taiwan’s population. The total sample size was 25,526 in 2020, with sampling errors equal to or less than 5% and confidence intervals (CIs) of 95%, which provided sufficient sample size and statistical power. Subsequently, a

computer-assisted telephone interview (CATI) survey was conducted from August to October 2020. Well-trained and experienced interviewers were employed in the CATI survey to ensure the quality of data collection. Data collected from the telephone survey questionnaire included information on sociodemographic characteristics (age, gender, education, occupation, and zip code of residence), LTPA behaviors, and self-evaluations (including health status and anthropometric variables [height and body weight]). Finally, 12,687 participants were enrolled into this study. This study was conducted in accordance with the Declaration of Helsinki, and all procedures were in accordance with the ethical standards of the Institutional Review Board of Fu Jen Catholic University in Taiwan (FJU- IRB C109085). Oral consent was provided by the participants before telephonic interviews.

Data collection

Sociodemographic characteristics such as age, gender, education, occupation, and zip code of residence; LTPA behaviors; and self-evaluations such as health status and anthropometrics variables (height and body weight) of the participants were recorded. The participants were divided into five groups according to their age (45–49, 50–54, 55–59, 60–64, and ≥ 65 years). Education was categorized into three levels (elementary school or lower, junior or senior high school, and college or higher). Occupation was categorized into 11 categories (white collar, government servant, blue collar, owner/manager, specialists, student, housewife, retired, freelancer, jobless, and other). Self-reported health status was categorized into three levels (excellent or good, fair, and very bad or poor).

Anthropometric variables and obesity status

Anthropometric variables such as height and body weight were obtained from the CATI survey, and BMI (kg/m^2) was further calculated. Then, BMI cut-off points were adopted as suggested by the Health Promotion Administration, Ministry of Health and Welfare in Taiwan including underweight ($\text{BMI} < 18.5 \text{ kg}/\text{m}^2$), normal weight ($18.5 \text{ kg}/\text{m}^2 \leq \text{BMI} < 24 \text{ kg}/\text{m}^2$), overweight ($24 \text{ kg}/\text{m}^2 \leq \text{BMI} < 27 \text{ kg}/\text{m}^2$), and obesity ($\text{BMI} \geq 27 \text{ kg}/\text{m}^2$) categories (Ministry of Health and Welfare, 2021).

LTPA assessment

The LTPA of the participants was assessed by a series of questions during the CATI survey. First, the participants were asked to describe their current LTPA participation. The question was as follows: “Have you participated in any LTPA in the past month?” Respondents who responded “yes” were then asked to note the frequency and duration of their participation in LTPA, with questions such as “How many times do you participate in LTPA per week?” and “How many minutes do you usually spend at one time?” Further, the intensity of LTPA was assessed based on the breathing and sweating status of the participants, through the question “When you are doing LTPA, you usually feel...” The participants chose their response from structural answers such as “no changes in my breath and sweating,” “I breathe faster but do not sweat,” “I breathe normally but sweat,” and “I breathe quickly and sweat.” Participants who reported that they usually breathed quickly and sweated were thus considered to engage in moderate-intensity LTPA. Thus, participants were dichotomized into regular and non-regular LTPA groups according to the physical activity (PA) recommendations specified in WHO guidelines. First, participants who

reported performing 150–300 minutes of moderate-intensity LTPA or 75–150 minutes of vigorous-intensity LTPA per week and responded “yes” to breathing quickly and sweating were classified into the regular LTPA group. The rest of the participants were categorized as the non-regular LTPA group.

Statistical analysis

Data were analyzed using SAS 9.4 (SAS Institute, Cary, NC, USA). Student’s *t*-test was performed to analyze continuous variables, and the chi-square test was used to analyze categorical variables. Multiple linear regression analysis with BMI as the dependent variable was used to examine the association of regular LTPA with BMI after adjustment for potential confounders. Adjusted odds ratios (ORs) with 95% CIs for obesity, overweight, or underweight were calculated from unconditional logistic regression models according to regular LTPA. Values are presented as means $\pm$ standard deviation or frequency percentages. Results were considered two-tailed and statistically significant at $p < 0.05$.

Results

A total of 12,687 participants were dichotomized into regular and nonregular LTPA groups based on their LTPA status. Their sociodemographic characteristics and anthropometric variables are presented in Table 1. All participants were divided into dichotomous groups, namely regular LTPA and nonregular LTPA groups; the nonregular LTPA group had a large proportion (79%) of participants. Except for BMI ($p = 0.063$), significant differences were observed between the groups ($p < 0.05$) in terms of all relevant variables, including age, gender, height, body weight, BMI, obesity status, education, occupation, and self-reported health status ($p < 0.05$). The regular LTPA group had a higher proportion of men (53.3%), higher proportion of normal-weight individuals (48.8%), and a higher education rate (27% of the participants had completed college education); almost 34.9% of the participants had already retired, and 75.5% self-reported that they were in excellent or good health.

Table 1
Demographic characteristics of the participants

Variables	LTPA Status		<i>P-value</i>
	Regular LTPA (<i>n</i> = 2,641)	Non-regular LTPA (<i>n</i> = 10,046)	
Age (y)			0.037*
45–49	427 (16.20%)	1655 (16.50%)	
50–54	480 (18.20%)	1647 (16.40%)	
55–59	434 (16.40%)	1721 (17.10%)	
60–64	438 (16.60%)	1525 (15.20%)	
≥ 65	862 (32.60%)	3497 (34.80%)	
Gender (% men)	1,407 (53.3%)	4,452 (44.3%)	< 0.001*
Height (cm)	163.62 ± 7.78	161.92 ± 7.95	< 0.001*
Body weight (kg)	64.60 ± 11.61	62.88 ± 11.63	< 0.001*
BMI (kg/m ²)	24.04 ± 3.38	23.90 ± 3.46	0.063
Obese Status (%)			< 0.001*
Underweight	53 (2.00%)	310 (3.10%)	
Normal weight	1289 (48.80%)	4805 (47.80%)	
Overweight	770 (29.20%)	2668 (26.60%)	
Obese	407 (15.40%)	1572 (15.60%)	
Education (%)			< 0.001*
Elementary school or lower	340 (13.00%)	1904 (19.10%)	
Junior or senior school	1570 (60.00%)	6100 (61.30%)	
College or higher	706 (27.00%)	1940 (19.50%)	
Occupation (%)			< 0.001*
White collar	287 (10.90%)	894 (9.00%)	

Abbreviations: BMI, body mass index; LTPA, leisure time physical activity

**p* < 0.05.

^aValues expressed as means ± standard deviation for continuous variables

Variables	LTPA Status		<i>P-value</i>
	Regular LTPA (<i>n</i> = 2,641)	Non-regular LTPA (<i>n</i> = 10,046)	
Government servant	161 (6.10%)	408 (4.10%)	
Blue collar	323 (12.30%)	1931 (19.40%)	
Owner/manager	194 (7.40%)	630 (6.30%)	
Specialists	104 (4.00%)	353 (3.50%)	
Student	0 (0.00%)	2 (0.00%)	
Housewife	433 (16.50%)	2124 (21.40%)	
Retired	917 (34.90%)	2790 (28.00%)	
Free lancer	121 (4.60%)	445 (4.50%)	
Jobless	69 (2.60%)	328 (3.30%)	
Other	15 (0.60%)	42 (0.40%)	
Self-reported health status (%)			< 0.001*
Excellent or good	1967 (77.50%)	6826 (71.90%)	
Fair	184 (7.30%)	902 (9.50%)	
Very bad or poor	386 (15.20%)	1767 (18.60%)	
Abbreviations: BMI, body mass index; LTPA, leisure time physical activity			
* <i>p</i> < 0.05.			
^a Values expressed as means ± standard deviation for continuous variables			

Table 2 presents the results of a comparison of BMI values between regular LTPA and nonregular LTPA status among middle-aged and older adults. Pooled data showed significant differences ($p < 0.05$) in the group of oldest (≥ 65 years) participants. Participants in the regular LTPA group had higher BMI values than other groups ($24.01 \pm 2.91 \text{ kg/m}^2$). In addition, BMI values significantly differed between regular LTPA and nonregular LTPA group among the youngest male participants (age, 45–49 years; $p < 0.05$). Men in the regular LTPA group had higher BMI values than those in the other group ($25.39 \pm 3.22 \text{ kg/m}^2$).

Table 2
Comparison of BMI values according to LTPA status among middle-aged and older adults in Taiwan

Variables	LTPA Status		<i>P-value</i>
	Regular LTPA	Non-regular LTPA	
Men (n = 5,502)			
45–49	25.39 ± 3.22	24.76 ± 3.16	0.015*
50–54	24.44 ± 2.65	24.75 ± 3.06	0.140
55–59	24.73 ± 2.84	24.39 ± 3.00	0.136
60–64	24.54 ± 2.44	24.31 ± 2.86	0.267
≥ 65	24.30 ± 2.59	24.05 ± 2.86	0.073
Women (n = 6,153)			
45–49	22.43 ± 2.29	22.54 ± 3.06	0.575
50–54	22.79 ± 2.73	23.00 ± 3.11	0.312
55–59	22.71 ± 2.92	23.09 ± 2.96	0.109
60–64	22.99 ± 2.91	23.24 ± 3.01	0.294
≥ 65	23.57 ± 3.28	23.45 ± 3.03	0.529
Pooled (n = 11,655)			
45–49	23.87 ± 3.15	23.52 ± 3.30	0.058
50–54	23.66 ± 2.81	23.72 ± 3.20	0.717
55–59	23.76 ± 3.05	23.66 ± 3.05	0.587
60–64	23.80 ± 2.78	23.73 ± 2.99	0.665
≥ 65	24.01 ± 2.91	23.74 ± 2.96	0.024*
Abbreviations: BMI, body mass index; LTPA, leisure time physical activity			
* <i>p</i> < 0.05.			

The results of the comparison between the prevalence of obesity status and LTPA status among middle-aged and older adults are shown in Table 3. With regard to obesity status, significant differences between regular LTPA and nonregular LTPA groups were found only in the underweight group in pooled data ($p < 0.05$) in the group of participants aged 50–54 years. A higher prevalence (4.00%) of underweight was observed in the nonregular LTPA group. After the separation of men and women, significant differences were observed between regular LTPA and nonregular LTPA groups in underweight participants aged 45–

49 years, and the nonregular LTPA group had a higher prevalence of underweight (men: 1.10%; women: 5.40%). Moreover, among participants aged 50–54 years, the prevalence of underweight significantly differed between regular LTPA and nonregular LTPA groups. The nonregular LTPA group had a higher prevalence of underweight than the other group (1.60%).

Table 3
Comparison between the prevalence of overweight/obesity and LTPA status
among middle-aged and older adults in Taiwan

Variables		LTPA Status		<i>P-value</i>
		Regular LTPA	Non-regular LTPA	
Men (n = 5,502)				
45–49	Underweight	0(00.00%)	7(01.10%)	0.004*
	Normal weight	76(38.60%)	262(39.50%)	
	Overweight	47(23.90%)	221(33.30%)	
	Obesity	74(37.60%)	174(26.20%)	
50–54	Underweight	0(00.00%)	10(01.60%)	0.001*
	Normal weight	98(40.80%)	232(37.10%)	
	Overweight	105(43.80%)	223(35.60%)	
	Obesity	37(15.40%)	161(25.70%)	
55–59	Underweight	3(01.40%)	13(01.80%)	0.170
	Normal weight	76(36.40%)	312(43.40%)	
	Overweight	90(43.10%)	251(34.90%)	
	Obesity	40(19.10%)	143(19.90%)	
60–64	Underweight	0 (00.00%)	15(02.20%)	0.127
	Normal weight	100(45.70%)	294(44.00%)	
	Overweight	85(38.80%)	242(36.20%)	
	Obesity	34(15.50%)	117(17.50%)	
≥ 65	Underweight	3(00.60%)	35(02.40%)	0.062
	Normal weight	219(46.40%)	728(48.90%)	
	Overweight	177(37.50%)	505(33.90%)	
	Obesity	73(15.50%)	220(14.80%)	
Women (n = 6,153)				
45–49	Underweight	11(05.30%)	45(05.40%)	0.003*
Abbreviation: LTPA, leisure time physical activity				
* <i>p</i> < 0.05.				

Variables		LTPA Status		P-value
		Regular LTPA	Non-regular LTPA	
	Normal weight	149(71.30%)	553(66.00%)	
	Overweight	44(21.10%)	151(18.00%)	
	Obesity	5(02.40%)	89(10.60%)	
50–54	Underweight	6(02.80%)	52(05.70%)	0.077
	Normal weight	146(67.60%)	538(59.10%)	
	Overweight	45(20.80%)	215(23.60%)	
	Obesity	19(08.80%)	106(11.60%)	
55–59	Underweight	7(03.60%)	40(04.40%)	0.131
	Normal weight	136(69.00%)	542(60.20%)	
	Overweight	36(18.30%)	225(25.00%)	
	Obesity	18(09.10%)	93(10.30%)	
60–64	Underweight	6(03.00%)	27(03.50%)	0.704
	Normal weight	125(63.10%)	460(59.80%)	
	Overweight	48(24.20%)	187(24.30%)	
	Obesity	19(09.60%)	95(12.40%)	
≥ 65	Underweight	17(05.30%)	63(04.00%)	0.404
	Normal weight	164(51.10%)	881(55.30%)	
	Overweight	93(29.00%)	449(28.20%)	
	Obesity	47(14.60%)	201(12.60%)	
Pooled (n = 11,655)				
45–49	Underweight	11(02.70%)	52(03.50%)	0.556
	Normal weight	225(55.40%)	815(54.30%)	
	Overweight	91(22.40%)	372(24.80%)	
	Obesity	79(19.50%)	262(17.50%)	
50–54	Underweight	7(01.50%)	62(04.00%)	0.001*
Abbreviation: LTPA, leisure time physical activity				
*p< 0.05.				

Variables		LTPA Status		<i>P-value</i>
		Regular LTPA	Non-regular LTPA	
	Normal weight	243(53.40%)	769(50.10%)	
	Overweight	150(33.00%)	438(28.50%)	
	Obesity	55(12.10%)	267(17.40%)	
55–59	Underweight	10(02.50%)	53(03.30%)	0.801
	Normal weight	213(52.30%)	855(52.80%)	
	Overweight	126(31.00%)	476(29.40%)	
	Obesity	58(14.30%)	236(14.60%)	
60–64	Underweight	6(01.40%)	42(02.90%)	0.239
	Normal weight	226(54.20%)	754(52.50%)	
	Overweight	132(31.70%)	429(29.90%)	
	Obesity	53(12.70%)	212(14.80%)	
≥ 65	Underweight	19(02.40%)	97(03.10%)	0.104
	Normal weight	383(48.30%)	1609(52.20%)	
	Overweight	271(34.20%)	953(30.90%)	
	Obesity	120(15.10%)	421(13.70%)	
Abbreviation: LTPA, leisure time physical activity				
* <i>p</i> < 0.05.				

Table 4 presents the results of multivariate regression for regular LTPA and BMI scores. The results indicated a positive relationship between regular LTPA and BMI scores ($\beta = 0.021$, $p < 0.05$) in Model 1. More regular LTPA translated to higher BMI scores. However, after adjustment for age, gender, self-reported health status, occupation, and education, no significant differences were found between regular LTPA and BMI scores ($p = 0.108$).

Table 4
Multivariate regression for regular LTPA to BMI scores

Variables	Model 1 (unadjusted)			Model 2 (adjusted ^a)		
	β	SE	<i>P</i> -value	β	SE	<i>P</i> -value
Regular LTPA	0.021	0.069	0.022*	0.015	0.068	0.108
Non-regular LTPA	Ref.	-	-	Ref.	-	-
Abbreviations: LTPA, leisure time physical activity; BMI: body mass index; SE, standard error						
* <i>p</i> < 0.05.						
^a Adjusted for age, gender, self-reported health status, occupation, and education						

The results of the multivariate logistic regression for regular LTPA and obesity, overweight, and underweight risk are shown in Table 5. Irrespective of adjustment for age, gender, self-reported health status, occupation, and education, a significant and negative relationship was observed between regular LTPA and underweight (Model 1: OR = 0.638, Model 2: OR = 0.713, *p* < 0.05).

Table 5
Multivariate logistic regression for regular LTPA and the risk of obesity, overweight, and underweight

Variables	Model 1 (unadjusted)			Model 2 (adjusted ^a)		
	OR	95% CI	<i>P</i> -value	OR	95% CI	<i>P</i> -value
Obesity						
Regular LTPA	1.035	0.913–1.173	0.590	0.985	0.862–1.125	0.822
Non-regular LTPA	Ref.	-	-	Ref.	-	-
Overweight						
Regular LTPA	1.076	0.972–1.190	0.157	1.046	0.941–1.162	0.403
Non-regular LTPA	Ref.	-	-	Ref.	-	-
Underweight						
Regular LTPA	0.638	0.474–0.859	0.003*	0.713	0.527–0.965	0.028*
Non-regular LTPA	Ref.	-	-	Ref.	-	-
Abbreviations: CI, confidence interval; LTPA, leisure time physical activity; OR, odds ratio						
* <i>p</i> < 0.05.						
^a Adjusted for age, gender, self-reported health status, occupation, and education.						

Discussion

To our knowledge, this is the first study to recruit middle-aged and older adults without regular LTPA by considering variety in gender, obesity status, health status, education, and occupation factors in Taiwan. The main findings of this study were as follows: (1) regular LTPA was associated with a reduced risk of underweight among middle-aged and older adults; and (2) in adults who performed regular LTPA, a higher proportion of them had normal weight, and excellent or good self-reported health status, and these adults had a lower rate of underweight compared with those with nonregular LTPA. These findings suggest that regular LTPA may maintain or promote a symmetric figure and perceived good health status as well as reduce the risk of underweight among middle-aged and elderly adults.

The associations of demographic variables such as age, gender, income, and residential location with PA have been reported [15]. For example, the proportion of physical inactivity is higher in women than in men (40% vs. 28%), and physical inactivity more common in high-income countries than in low-income countries (45% vs. 25%) and more prevalent in the Americas than in Southeast Asia (43% vs. 17%) [8]. In the present study, regular LTPA was associated with male sex (53%), normal weight (49%), college education (27%), and being retired (35%), and 76% of the participants reported excellent or good self-reported health status.

ACSM suggested that both moderate- and vigorous-intensity PA (for ≥ 150 min/week and ≥ 75 min/week, respectively) had beneficial effects on weight management and reduced the risk of chronic diseases, cognitive impairment, disability, and premature mortality [4, 5, 14]. Hallal *et al.* reported that the participation of adults in moderate- and vigorous-intensity PA decreased with age [8]. In the present study, we observed that only 21% of middle-aged and elderly adults performed regular LTPA in Taiwan. Notably, the proportion of regular LTPA among adults increased with age, from 16–18% among middle-aged adults to 33% among elderly adults. A similar study reported that PA levels generally decrease with age, whereas an improvement in regular PA was observed as adults reached retirement age (≥ 65 years) [16]. Future research should investigate whether an internal or external motivation (e.g., healthy concept enhancement, national policy development, economic pressure release, and sociocultural change) for adults promotes regular LTPA during at retirement age.

A study reported that BMI was significantly associated with dependency during activities of daily living in elderly individuals and that this dependency decreased in the presence of LTPA. Moreover, no significant interaction was noted between BMI and LTPA with regard to their association with dependency in activities of daily living, which indicates substantial confounding effects between BMI and LTPA [17]. In this study, we found that regular LTPA was associated with BMI among middle-aged and elderly adults but became nonsignificant after adjustment for confounding factors such as age, gender, self-reported health status, occupation, and education. Confounding factors may overestimate or underestimate the real magnitude of an association or even change the direction of a real association [18]. Therefore, the use of properly adjusted confounding factors is necessary to avoid bias and distortion.

Notably, previous studies have indicated that underweight was associated with increased all-cause mortality compared with normal weight [19, 20]. This high mortality among individuals with underweight may be attributable to smoking, preexisting illness, and increased risk of injury and impaired survival after an accident [19]. In the current study, we observed that regular LTPA was associated with a reduced risk of underweight (BMI < 18.5 kg/m²). Compared with nonregular LTPA, regular LTPA was associated with a lower prevalence of underweight in men (aged 45–54 years) and women (aged 45–49 years). A study reported a significant correlation between PA and muscle mass among young and older adults [21, 22]. Sagiv *et al.* indicated that regular PA reduced height loss due to aging in both men and women [23]. Therefore, we speculate that regular LTPA may promote muscle mass and bone health and prevent height loss [14, 23], resulting in an optimization in BMI and prevention of underweight among middle-age adults.

The present study has some limitations. First, this study did not measure the body fat percentage, muscle mass, and bone mineral density of the participants. Without these measurements, it may be difficult to comprehensively elucidate the mechanisms underlying the reduction of the risk of underweight by regular LTPA. Second, our questionnaire did not include the reason for participation in regular LTPA by the participants; thus, the motivation behind the improved and regular LTPA observed among adults during retirement age remains unclear.

Conclusions

This study demonstrated that regular LTPA was associated with a reduced risk of underweight among middle-aged and elderly adults. Regular LTPA showed no relationship with BMI and obesity after adjustment for confounding factors (e.g., age, gender, and occupation). Further research on the association between regular LTPA, body fat percentage, and bone mineral density in Taiwanese adults is warranted.

Abbreviations

ACSM: American College of Sports Medicine; BMI: Body mass index; CATI: two-month telephone interview; CI: confidence interval; LTPA: Leisure-time physical activity; OR: odds ratio; PA: physical activity; SD: standard deviation; TNPAS: Taiwan's National Physical Activity Survey.

Declarations

Acknowledgments

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Authors' contributions

YTC participated in the design, conducted the statistical analyses, interpreted the data, and drafted the manuscript. PFL and CFL helped in conducting the study and revising the manuscript. AC and YCC helped to manage and analyze the data. CCH supervised the study and critically reviewed and revised the manuscript. All authors read and approved the final manuscript.

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Availability of data and material

The data that support the findings of this study are available from [the Sports Cloud: Information and Application Research Center of Sports for All, Sport Administration, Ministry of Education in 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 Sports Cloud: Information and Application Research Center of Sports for All, Sport Administration, Ministry of Education in Taiwan].

Ethics approval and consent to participate

This study was conducted with a secondary database provided by the Sports Cloud: Information and Application Research Center of Sports for All, Sport Administration, Ministry of Education in Taiwan. All consents obtained from the study participants were written prior the data collection. This study's design and analysis procedure was approved by the Ethical Committee of Fu Jen Catholic University (FJU-IRB-C108088).

Consent for publication

Not applicable.

Consent for publication

Participants were provided a study overview and oral consent was attained.

Competing interests

The authors declare that they have no competing interests.

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