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Original article

Leisure-time physical activity and mortality risk in type 2 diabetes: A nationwide cohort study

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A B S T R A C T

Aim: Physical activity improves insulin resistance, inhibits inflammation, and decreases the incidence of cardiovascular disease. These are major causes of death in patients with diabetes.
Methods: The Taiwan National Health Interview Survey collected baseline characteristics of socioeconomic level, education, marriage, and health behaviour, including leisure time physical activity in 2001, 2005, 2009, and 2013. The National Health Insurance research dataset 2000–2016 contained detailed information on medical conditions, including all comorbidities. All-cause and cardiovascular deaths were confirmed by the National Death Registry.
Results: A total of 4859 adults with type 2 diabetes were included in the analysis; 2389 (49 %) were men and the mean±SD age was 60±13 years. Kaplan-Meier curve of all-cause (log-rank P<0.001) and cardiovascular death (log-rank P=0.038) categorized by leisure-time physical activity showed a significant difference. The multivariable Cox regression model showed that those who had more leisure time physical activity had a significantly lower risk of all-cause death than those with no physical activity (physical activity of 1-800 MET-min/week HR = 0.66, 95% CI: 0.54–0.81, physical activity of >800 MET-min/week HR = 0.67, 95% CI: 0.56-0.81). A significant trend was also observed (P <0.001). Similar results were also observed for cardiovascular mortality (physical activity of 1-800 MET-min/week HR = 0.54, 95% CI: 0.36–0.84, physical activity of >800 MET-min/week HR = 0.78, 95% CI: 0.55–1.13).
Conclusion: For those with diabetes, increased leisure-time physical activity significantly reduced risk of all-cause and cardiovascular death. Further research is warranted to determine the proper prescription for physical activity to prolong healthy life.

Introduction

The global prevalence of diabetes in 20–79 year olds was 10.5% in 2021. This represents nearly 536.6 million people, and the prevalence is increasing rapidly [1]. The defining pathogenic mechanism of type 2 diabetes is insulin resistance and the lowering of insulin secretion. This leads to glucose metabolism imbalance and triggers oxidative stress and inflammatory responses. Insulin resistance can also cause dyslipidaemia, endothelial dysfunction, and atherosclerotic plaque formation. These mechanisms are related to the incidence of cardiovascular diseases [2]. Cardiovascular morbidity and related deaths are prevalent in people with diabetes [3]. It destroys their quality of life and results in enormous health expenditures [4].

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Exercise is known to improve insulin resistance [5]. Exercise training increases glucose uptake and usage, increases lipid hydrolysis oxidation, alleviates systemic inflammation, and improves metabolic pathways in people with diabetes [6]. Therefore, exercise is associated with a reduced cardiovascular disease risk and significant health benefits [7]. Several longitudinal studies have demonstrated that increasing exercise can reduce all-cause mortality and moderately increase life expectancy [8, 9]. This effect is strongly associated with a reduced risk of cardiovascular disease.

Moe et al. investigated the relationship between leisure-time physical activity and cardiovascular death in subjects with diabetes by using data from the Nord-Trøndelag Health Study. The study reported that even a minor amount of physical activity may decrease cardiovascular death in individuals with diabetes [10]. Other studies have confirmed that exercise can reduce the incidence of cardiovascular disease and all-cause death in people with diabetes [11]. Prior studies used several measurements of physical activity, such as fitness by treadmill test, physical activity intensity, frequency, and leisure-time physical activity, collected by questionnaires. Moreover, most of the studies were performed in Europe and the United States. However, Asian studies were lacking.

Shin analysed the Korean National Health Insurance Service-Health Screening Database and reported a U-shaped relationship between exercise frequency and mortality in people with diabetes [12]. A report from the Health Professionals' Follow-up Study in the US also showed that leisure-time physical activity was associated with a decreased risk of cardiovascular disease, cardiovascular mortality, and all-cause mortality in men with type 2 diabetes [13]. However, females were not included in the analysis.

The current recommendations of physical activity for people with type 2 diabetes are based on efficacy of glycemic control. Regarding recommendations on physical activity for diabetic patients, the proper type, intensity, and frequency of physical activity to prevent complication and prolong life expectancy remains unknown [14]. Thus, we performed this research to examine the relationship between leisure-time physical activity, cardiovascular, and all-cause death in patients with type 2 diabetes.

Material and methods

Dataset and study design

The Taiwan Health Promotion Administration had conducted a national health survey every four years since 2001. Participants were enrolled using a multistage stratified systematic sampling method. Information on the study subjects, including socioeconomic status, education level, household income, marital status, and health habits, was obtained through face-to-face interviews. The current research analysed data from the four waves of the National Health Interview Survey (NHIS) in 2001, 2005, 2009, and 2013. In addition, the National Health Insurance dataset and National Death Registration are linked. The National Health Insurance dataset contains lifelong health information on more than 99% of Taiwanese residents. It contains both outpatient and inpatient medical records. This was a prospective cohort study. We chose people aged more than 18 years with type 2 diabetes from the NHIS 2001, 2005, 2009, and 2013. Diabetes mellitus was defined when the disease diagnosis code (ICD-9-CM code 250) was noted in more than three outpatient medical records or one inpatient medical record. The study subjects were followed starting from the date of the health survey and ending at the date of death or on December 31, 2016.

Leisure time physical activity

Participants' physical activity during leisure time at baseline was gathered by asking the questions: "How often do you exercise every week? What type of exercise do you do? How long do you exercise?" The leisure time physical activity level was quantified in metabolic equivalent (MET) minutes per week from answers to the questionnaire on the frequency and duration of exercise [15]. More than 30 types of activity were listed in the questionnaire, such as walking, swimming, running, bicycling, golf, tennis, basketball, dancing, yoga, hiking, and so on. A total of up to 5 types of physical activity were collected through interview. The sum of the 5 types of physical activity were analysed in this research. Participants were divided according to their tertiles of leisure time physical activity intensity: 0, 1-800, and >800 MET-min/week; duration: 0, 1-210, >210 min/week; and frequency: 0, 1-6, >6 time/week.

Ascertainment of mortality

All-cause and cardiovascular deaths were ascertained by the National Death Registration from 2000 to 2016. The causes of death were recorded using the International Classification of Diseases, Tenth Revision (ICD-10; codes A00–Z99). Cardiovascular mortality was coded as I00–I99 in the ICD-10.

Potential confounders

Baseline participant characteristics, including marriage, education level, household income, and health habits, were collected by well-trained interviewers. Body mass index was defined as body weight (kg) divided by the square of body height (m). The category of body mass index was calculated according to the recommendation of the Taiwan Health Promotion Administration as: underweight (<18.5 kg/m^2), normal (18.5–23.9 kg/m^2), overweight (24–26.9 kg/m^2), and obese (≥27 kg/m^2) [16]. Smoking habits were categorized as: never, current, or a former smoker. The frequency of alcohol intake per week was divided into three groups: no drinking, less than once a week, and more than once a week [17, 18]. Vegetable and fruit intake was categorized as: less than 5 days per week and 5–7 days per week.

Comorbidities, such as liver cirrhosis, chronic renal failure, stroke, heart failure, and cancer, were confirmed from the National Health Insurance dataset. Disease diagnosis was recorded using the International Classification of Disease, 9th Revision Clinical Modification (ICD-9-CM). Comorbidity was defined when the disease diagnosis code was noted in more than three outpatient medical records or one inpatient medical record. [19]. The diagnosis codes of the comorbidities included liver cirrhosis (ICD-9-CM codes 571.2 and 571.5), chronic renal failure (ICD-9-CM codes 580-589), stroke (ICD-9-CM codes 430-438), heart failure (ICD-9-CM codes 428), hypertension (ICD-9-CM codes 401-405), dyslipidaemia (ICD-9-CM codes 272), chronic obstructive pulmonary disease (ICD-9-CM codes 496), depression (ICD-9-CM codes 296.2, 296.3, 300.4, and 311), and cancer (ICD-9-CM codes 140-208).

Statistical analysis

Data are presented as mean ± SD or number (%). First, we drew the Kaplan–Meier survival curves with the log-rank test to observe the differences across the three categories of leisure-time physical activity. Cox regression models were used to calculate hazard ratios (HRs) and 95% confidence intervals (CIs). Those with no physical activity during leisure time (0 MET-min/week, 0 min/week, and 0 time/week) were used as the reference group. The confounding variables in the multivariable Cox models were: age, sex, body mass index, marital status, education, household income, cigarette smoking and alcohol consumption, weekly consumption of vegetables and fruit, and comorbidities, including liver cirrhosis, chronic renal failure, stroke, heart failure, hypertension, dyslipidaemia, chronic obstructive pulmonary disease, depression, and cancer. Age was used as the time scale in this study. Testing for trend was used to evaluate dose-response effect of physical activity on mortality. Sensitivity analysis was performed by excluding subjects who died during the first then first and second years of follow-up, using age as the time scale and included the same confounding factors. Data analyses were performed using the SAS software (version 9.4; SAS Institute, Cary NC).

Results

During the four waves of the NHIS, including NHIS 2001, 2005, 2009, and 2013,

A total of 4859 adults aged > 18 years with type 2 diabetes participated in the survey (Supplementary figure 1). Among them, 2389 (49%) were male, and the mean±SD age was 60±13 years. The follow-up period was 2001 to 2016. Fig. 1 shows the Kaplan−Meier survival curves of the three groups with leisure-time physical activity. It indicated a significant difference in all-cause mortality (*p*-value of log-rank test <0.001) and cardiovascular mortality (*p*-value of log-rank test =0.038). Only the comparison of 0 MET-min/week and >800 MET-min/week was statistically significant in all-cause mortality (*p*=0.002), for cardiovascular mortality this comparison had a *p*=0.069. No statistically significance was noted for the comparisons of 0 MET-min/week and 1-800 MET-min/week (*p*=0.157), 1-800 MET-min/week and >800 MET-min/week (*p*=0.128) in all-cause mortality. No statistically significance was noted for the comparisons of 0 MET-min/week and 1-800 MET-min/week (*p*=0.118), 1-800 MET-min/week and >800 MET-min/week (*p*=0.849) in cardiovascular mortality.

Table 1 shows the baseline characteristics of the participants and Table 2 shows the description of baseline leisure-time physical activity. Regarding the leisure-time physical activity categories, 1798 (37%), 1347 (27.72%), and 1714 (35.27%) participants were categorized as 0 MET-min/week, 1-800 MET-min/week, and >800 MET-min/week, respectively. During the 17 years of follow-up, 996

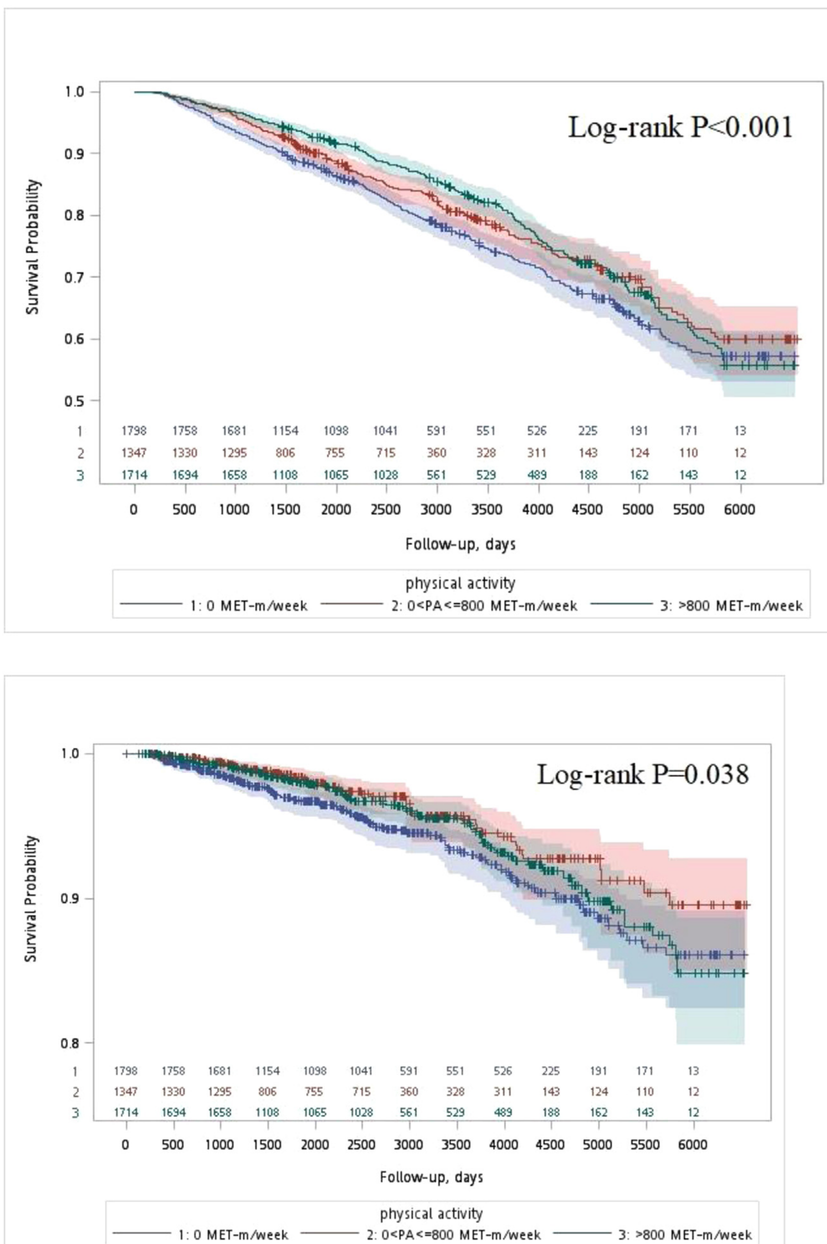

Fig 1. Kaplan−Meier survival curve estimates for all-cause and cardiovascular mortality in people with type 2 diabetes The relation of leisure-time physical activity with all-cause mortality.

Table 1
Characteristic of study population.

Demographics	Total Numbers (% in column) *n*=4859	Number of death (% in row) *n*=996	Number of cardiovascular death (% in row) *n*=239
Age (years)	**60** ± 13	67 ± 12	69 ± 11
Sex			
Female	2470 (51%)	451 (18%)	101 (4.1%)
Male	2389 (49%)	545 (23%)	138 (5.8%)
Marital Status			
Married	3544 (73%)	649 (18%)	168 (4.7%)
Unmarried	286 (5.9%)	41 (14%)	9 (3.2%)
Widowed/divorced	1019 (21%)	305 (30%)	62 (6.1%)
Education level			
Low (elementary or below)	2432 (51%)	682 (28%)	165 (6.8%)
Moderate (junior/senior high)	1628 (34%)	224 (14%)	51 (3.1%)
High (college or above)	694 (15%)	78 (11%)	21 (3.0%)
Household income			
<US$952/month	1652 (39%)	451 (27%)	110 (6.7%)
US$952-2,222/month	1607 (38%)	283 (18%)	69 (4.3%)
>US$2,222/month	1024 (24%)	174 (17%)	44 (4.3%)
Smoking Status			
No	3318 (68%)	654 (20%)	156 (4.7%)
Current	938 (19%)	207 (22%)	48 (5.1%)
Former	601 (12%)	135 (22%)	35 (5.8%)
Alcohol Intake			
No	3108 (70%)	753 (24%)	188 (6.1%)
<1 time/week	747 (17%)	83 (11%)	17 (2.3%)
>1 time/week	561 (13%)	98 (17%)	19 (3.4%)
Vegetable Intake			
<5 days/week	327 (6.8%)	125 (38%)	35 (11%)
	4519 (93%)	868 (19%)	203 (4.5%)
>5 days/week			
Fruit Intake			
<5 days/week	1056 (22%)	373 (35%)	98 (9.3%)
>5 days/week	3772 (78%)	618 (16%)	140 (3.7%)
BMI (kg/m^2)			
Underweight (<18.5)	93 (2.0%)	38 (41%)	9 (9.7%)
Normal weight (18.5–23.9)	1584 (35%)	371 (23%)	89 (5.6%)
Overweight (24–26.9)	1405 (31%)	235 (17%)	57 (4.1%)
Obesity (≥27)	1470 (32%)	211 (14%)	52 (3.5%)
Comorbidities			
Liver cirrhosis			
No	4589 (94%)	865 (19%)	229 (4.5%)
Yes	270 (5.6%)	131 (49%)	10 (3.7%)
Chronic renal failure			
No	4168 (86%)	742 (18%)	167 (4.0%)
Yes	691 (14%)	254 (37%)	72 (10%)
Stroke			
No	3500 (72%)	501 (14%)	135 (3.2%)
Yes	1359 (28%)	495 (36%)	104 (16%)
Heart failure			
No	4208 (87%)	675 (16%)	81 (2.3%)
Yes	651 (13%)	321 (49%)	158 (12%)
Cancer			
No	4133 (85%)	659 (16%)	199 (4.8%)
Yes	726 (15%)	337 (46 %)	40 (5.5%)
Hypertension			
No	1076 (22%)	132 (12%)	15 (1.4%)
Yes	3783 (78%)	864 (23%)	224 (5.9%)
Dyslipidaemia			
No	1175 (24%)	428 (36%)	105 (8.9%)
Yes	3684 (76%)	568 (15%)	134 (3.6%)
COPD			
No	3264 (67%)	608 (19%)	133 (4.1%)
Yes	1595 (33%)	388 (24%)	106 (6.7%)
Depression			
No	4024 (83%)	867 (22%)	209 (5.2%)
Yes	835 (17%)	129 (15%)	30 (3.6%)

Abbreviations: BMI, body mass index; COPD, chronic obstructive pulmonary disease

(20.50%) deaths were observed. Among them, 432 (24.03%), 245 (18.19%), and 319 (18.61%) participants had leisure-time physical activity of 0 MET-min/week, 1-800 MET-min/week, and >800 MET-min/week, respectively.

Table 3 shows the results of the univariate Cox regression models. Compared with those who had leisure-time physical activity of 0 MET-min/week, participants with 1-800 MET-min/week had a lower risk of mortality (hazard ratio [HR], 0.82; 95% confidence interval

Table 2
Description of baseline leisure-time physical activity.

Leisure-time physical activity	Total Numbers (% in column) *n*=4859	Number of death (% in row) *n*=996	Number of cardiovascular death (% in row) *n*=239
Intensity of activity (MET-min/week)			
0	1798 (37%)	432 (24%)	108 (6.0%)
1−800	1347 (28%)	245 (18%)	48 (3.6%)
>800	1714 (35%)	319 (19%)	83 (4.8%)
Duration of activity (min/week)			
0	1798 (37%)	432 (24%)	108 (6.0%)
1−210	1642 (34%)	313 (19%)	68 (4.1%)
>210	1419 (29%)	251 (18%)	63 (4.4%)
Frequency of activity (time/week)			
0	1798 (37%)	432 (24%)	108 (6.0%)
1−6	1311 (27%)	245 (14%)	31 (2.4%)
>6	1750 (36%)	319 (22%)	100 (5.7%)

[CI], 0.70-0.96; p=0.014). Participants with leisure-time physical activity >800 MET-min/week also had significantly lower risk of mortality (HR, 0.77; 95% CI, 0.67−0.89; p=0.001). Compared with those who had leisure-time physical activity of 0 min/week, participants with 1-210 min/week (HR, 0.84; 95% CI, 0.72−0.97; p=0.017) and >210 min/week (HR, 0.74; 95% CI, 0.64-0.87; p<0.001) had significantly lower risk of mortality. Participants with physical activity of 1−6 time/week had a lower risk of mortality (HR, 0.57; 95% CI, 0.48−0.68; p<0.001), compared with those who had leisure-time physical activity of 0 time/week. As for cardiovascular mortality, participants with physical activity of 1-800 MET-min/week (HR, 0.65; 95% CI, 0.47−0.92; p=0.013), 1-210 min/week (HR, 0.73; 95% CI, 0.54−0.99; p=0.045), and 1-6 time/week (HR, 0.40; 95% CI, 0.27−0.59; p<0.001) had significant decreased risks, compared with those with no leisure-time physical activity. In addition, older age, male sex, obesity, widowed/divorced/separated, low education level, low household income, current and former smokers, regular alcohol consumption, less fruit and vegetable intake, underweight, and those with comorbidities were associated with a higher risk of all-cause death (p<0.001).

The results of the multivariable Cox regression model are presented in Table 4. After controlling for potential confounders, subjects with leisure-time physical activity of 1-800 MET-min/week and >800 MET-min/week had a significantly decreased risk of mortality (1-800 MET-min/week: HR, 0.66; 95% CI, 0.54−0.81; p-value<0.001; >800 MET-min/week: HR, 0.67; 95% CI, 0.56−0.81; p-value<0.001). In addition, a significant dose-response relationship between leisure-time physical activity and decreased risk of mortality was noted in the trend test (p for trend<0.001). Other independent variables that increased the risk of mortality included age, male sex, being underweight, current smoking, regular alcohol consumption, less fruit and vegetable intake, and comorbidities, including diabetes, liver cirrhosis, chronic renal failure, stroke, heart failure, chronic obstructive pulmonary disease, depression, and cancer.

As for cardiovascular mortality, after all potential confounders were adjusted, those with leisure time physical activity of 1-800 MET-min/week had significantly decreased risk of cardiovascular mortality (HR, 0.54; 95% CI, 0.36−0.84; p-value=0.005. In addition, a significant dose-response relationship was noted between leisure-time physical activity and decreased risk of cardiovascular death (p for trend=0.036). Those with physical activity of 1-210 min/week (HR, 0.68; 95% CI, 0.46−0.99; p-value=0.042) and 1-6 time/week (HR, 0.59; 95% CI, 0.37−0.93; p-value=0.023) had significant decreased cardiovascular risk than those with no physical activity. Fig. 2 shows the spline curves of leisure-time physical activity as a continuous variable with all-cause and cardiovascular mortality.

To account for reverse causality, sensitivity analysis was performed by excluding subjects who died during the first 2 years of follow-up. This was completed to strengthen the risk estimation and the hazards ratios were very similar. After excluding 40 participants who died in the first year, 4819 participants were analysed. The results showed that those with leisure-time physical activity of 1-800 MET-min/week and > 800 MET-min/week had a significantly decreased risk of mortality (1-800 MET-min/week: HR, 0.75; 95% CI, 0.61−0.91; p-value=0.004; >800 MET-min/week: HR, 0.67; 95% CI, 0.56−0.80; p-value<0.001). After excluding 138 participants who

Table 3
Univariate Cox regression analysis of all-cause and cardiovascular mortality according to leisure-time physical activity.

	All-cause mortality			Cardiovascular mortality		
Leisure-time physical activity	HR	(95% CI)	*p*-value	HR	(95% CI)	*p*-value
Intensity of activity (MET-min/week)						
0	ref			ref		
1−800	0.82	(0.70−0.96)	0.014	0.65	(0.47−0.92)	0.013
>800	0.77	(0.67−0.89)	0.001	0.81	(0.61−1.07)	0.142
Duration of activity (min/week)						
0	ref			ref		
1−210	0.84	(0.72−0.97)	0.017	0.73	(0.54−0.99)	0.045
>210	0.74	(0.64−0.87)	<0.001	0.75	(0.55−1.03)	0.072
Frequency of activity (time/week)						
0	ref			ref		
1−6	0.57	(0.48−0.68)	<0.001	0.40	(0.27−0.59)	<0.001
>6	0.97	(0.84−1.11)	0.632	1.02	(0.77−1.33)	0.908

Abbreviations: HR, hazard ratio; CI, confidence interval

Table 4
Adjusted hazards ratios for all-cause and for cardiovascular mortality according to leisure-time physical activity; 4859 participants from the Taiwan National Health Interview Survey.

	All-cause mortality			Cardiovascular mortality		
Leisure-time physical activity	HR	(95% CI)	*p*-value	HR	(95% CI)	*p*-value
Intensity of activity (MET-min/week)						
0	ref			ref		
1−800	0.66	(0.54−0.81)	<0.001	0.54	(0.36−0.84)	0.005
>800	0.67	(0.56−0.81)	<0.001	0.78	(0.55−1.13)	0.187
Duration of activity (min/week)						
0	ref			ref		
1−210	0.66	(0.55−0.80)	<0.001	0.68	(0.46−0.99)	0.042
>210	0.65	(0.54−0.79)	<0.001	0.83	(0.56−1.24)	0.361
Frequency of activity (time/week)						
0	ref			ref		
1−6	0.72	(0.58−0.89)	0.002	0.59	(0.37−0.93)	0.023
>6	0.64	(0.54−0.77)	<0.001	0.73	(0.51−1.04)	0.077

Abbreviations: HR, hazard ratio; CI, confidence interval.
Adjusted for: age, sex, marital status, education level, household income, smoking status, alcohol, vegetable, and fruit intakes, body mass index, and comorbidities (liver cirrhosis, chronic renal failure, stroke, heart failure, hypertension, dyslipidaemia, chronic obstructive pulmonary disease, depression and cancer).

died in the first two years of the study period, 4721 participants were analysed, and the results showed that those with leisure-time physical activity of 1-800 MET-min/week and > 800 MET-min/week had a significantly decreased risk of mortality (1-800 MET-min/week: HR, 0.84; 95% CI, 0.65−0.99; *p*-value=0.043; >800 MET-min/week: HR, 0.71; 95% CI, 0.58−0.85; *p*-value<0.001) (Supplementary table 1). Sensitivity analysis of cardiovascular mortality also showed a significant association after excluding death during the first year of the study period (Supplementary table 2).

Discussion

The current cohort study showed that increased leisure-time physical activity in diabetes patients had a significantly lower risk of all-cause and cardiovascular death, with a significant trend.

Diabetes mellitus is commonly associated with hypertension and hyperlipidaemia. These are major risk factors for cardiovascular disease [20]. Patients with diabetes often have elevated blood glucose levels and blood pressure levels, which cause vascular endothelial dysfunction. This leads to atherosclerosis and cardiovascular disease [21]. Cardiovascular mortality, caused by various cardiovascular diseases, is the principal cause of death among people with diabetes [22]. Previous studies have demonstrated that exercise intervention improves endothelial function which is quantified by flow-mediated dilation in the brachial artery [23]. Both aerobic and combined exercise training can improve endothelial function [24]. Exercise also enhances insulin sensitivity and glycaemic control, increases muscle mass, and reduces weight [25]. According to previous studies, exercise is consistently associated with a reduced risk of cardiovascular disease [7]. Both occupational and leisure-time physical activity have been reported to reduce the risk of coronary artery disease and stroke incidence [26]. In addition, in vitro studies have shown that physical activity in obese mice decreases the expression of inflammatory cytokines, such as tumor necrosis factor-α, monocyte chemoattractant protein-1, and plasminogen activator inhibitor-1 in adipose tissue [27]. Human studies have also shown that physical activity is associated with anti-inflammatory effects with decreased levels of Interleukin-6 and C-reactive protein [28].

Association between physical activity and death are still not fully investigated [29, 30]. The results of the current study were compatible with those of previous research, although there is a diverse approach to calculating physical activity capacity in the various studies. The Aerobics Center Longitudinal Study demonstrated an inverse association between exercise capacity and mortality in men with diabetes and this association was independent of body mass index [31]. Exercise capacity was measured using a modified Balke treadmill exercise test. Leisure-time physical activity was not assessed and females were not included in this study. A European cohort study of 5859 individuals with diabetes reported that physical activity was associated with a lower risk of cardiovascular disease and all-cause death. In addition, walking is also associated with a lower risk of cardiovascular death [32]. Information on physical activity was collected using an interview questionnaire and calculated using the Cambridge Physical Activity Index. This index contains self-reported total activity. It includes work-related activity as well as leisure time activities such as cycling and sports [33]. The independent effects of occupational and leisure-time physical activity were not analysed separately. A previous report from Nylen et al. showed that exercise capacity reduces the risk of all-cause death in men aged 50-87 years with diabetes mellitus [34]. Exercise tolerance testing was performed to evaluate the exercise capacity of the study participants. Leisure-time physical activity was not measured in this study. In addition, the results are based only on males aged 50-87 years and cannot be extended to females or those aged < 50 years. Previous research has demonstrated that both exercise capacity and physical activity are associated with decreased risk of death in people with diabetes. However, the optimal regimen has not been well documented. According to the 2020 WHO guidelines, all adults should undertake 150-300 min of moderate-intensity, or 75−150 min of vigorous-intensity physical activity, or some equivalent combination of moderate-intensity and vigorous-intensity aerobic physical activity, per week. These criteria were not analysed in the current study because participants were divided according to their tertiles of leisure time physical activity. The results of this study were compatible with the 2020 WHO guidelines that people with diabetes would have decreased mortality risks if they had increased physical activity intensity, duration, and frequency.

This study has several strengths. This was the first study in Asia to investigate the association between leisure-time physical activity and cardiovascular and all-cause mortality in diabetes. The NHIS is a population-based cohort with good generalizability for the Taiwanese population. Detailed information on the participants' characteristics were collected. This included body mass index, socioeconomic level, diet, smoking, physical activity, and comorbidities. Thus, we adjusted for nearly all possible potential confounders. There are some limitations that must be mentioned. Leisure-time physical activity was self-reported and occupation-related physical activity was not assessed. Thus, this may lead to some overestimation or

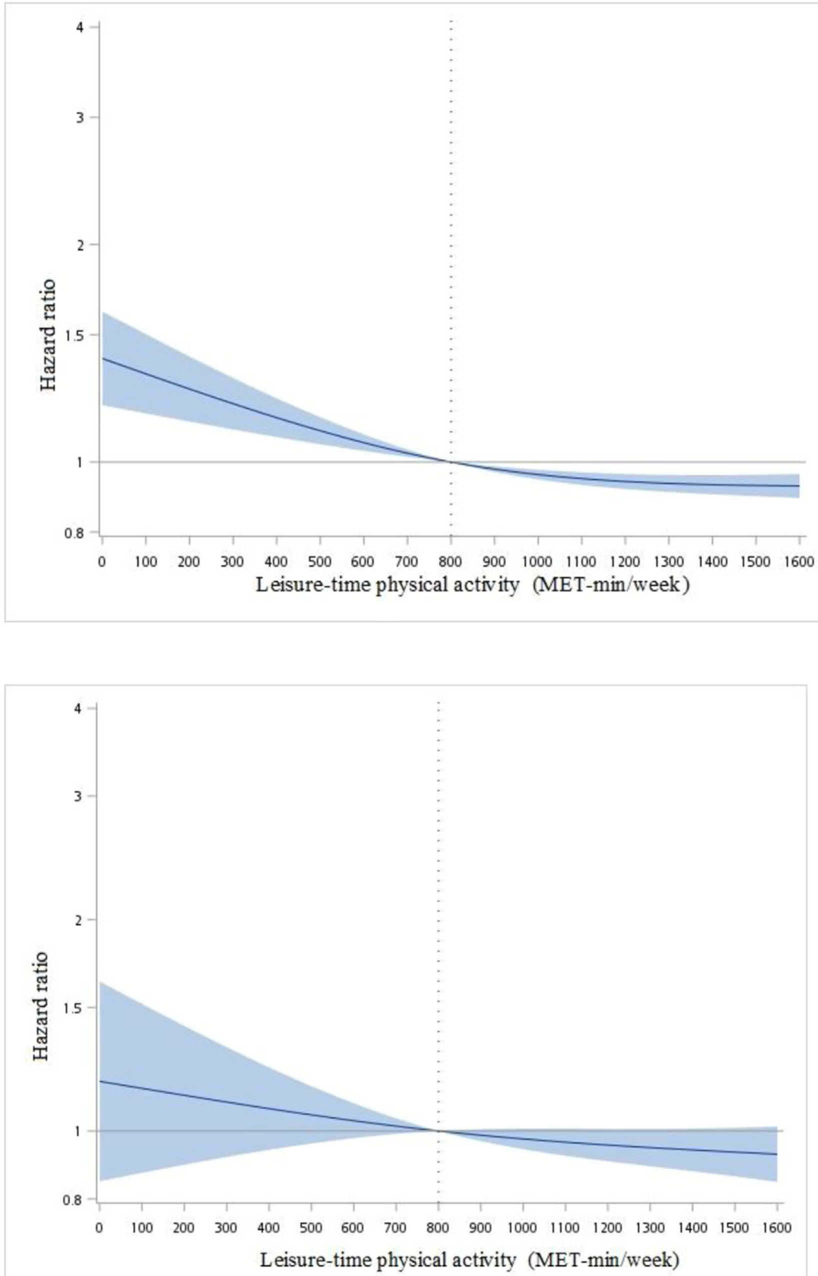

Fig. 2. Spline curve of all-cause and cardiovascular mortality according to leisure-time physical activity in people with type 2 diabetes. Adjusted for: age, sex, marital status, education level, household income, smoking status, alcohol, vegetable, and fruit intakes, body mass index, and comorbidities (liver cirrhosis, chronic renal failure, stroke, heart failure, hypertension, dyslipidaemia, chronic obstructive pulmonary disease, depression and cancer).

underestimation of the true activity level of the participants. In addition, recall bias and misclassification bias must also be considered, since leisure-time physical activity was not measured by validated actigraphy. Leisure-time physical activity was evaluated at baseline and changes in physical activity over the study period were not assessed. The interaction term between leisure-time physical activity and body mass index was not analysed. Clinical data on aspects such as duration, medication, and severity of diabetes mellitus, including fasting glucose or HbA1c at baseline were not available in the dataset.

Conclusion

For those with diabetes, increased leisure-time physical activity significantly reduced the risk of all-cause and cardiovascular death. Further studies are warranted to investigate the proper intensity, frequency, and duration of leisure-time physical activity to promote health and reduce mortality risk in individuals with type 2 diabetes.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.diabet.2022.101378.

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