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Physical activity is associated with lower health care costs among Taiwanese individuals with diabetes mellitus

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Abstract

The economic burden of diabetes has increased over time with disease severity. Previous publications investigating the effects of physical activity (PA) on medical costs have made use of small sample sizes. We assessed the relationship between PA and 1-year medical expenditure among Taiwanese patients with type-2 diabetes mellitus (T2DM).

Data were recruited from three governmental databases, including the 2012 adult preventive health service database. Participants were grouped as inactive (no exercise), insufficiently active (exercise < 150 minutes/week), and sufficiently active (exercise >150 minutes/week) individuals. Patients were stratified according to age and Charlson score. Multivariate linear regression models were used to determine β-coefficients and their *P* values.

Overall, 218,960 individuals were identified with diabetes. The prevalence of the disease was 13.1% among sufficiently active, 35% among insufficiently active, and 51.9% among physically inactive adults. In general, patients who had exercise >150 minutes/week had lower health care spending (i.e., US$ 755.83) followed by those who had less than 150 minutes/week (US$ 880.08) when compared with inactive patients ($P < .0001$). Moreover, health care costs derived from outpatient or inpatient care were lower for sufficiently active than inactive participants ($P < .0001$).

Compared with being sedentary, PA was associated with lower health care costs of Taiwanese adults with diabetes mellitus.

Abbreviations: β = beta-coefficient, ANOVA = analysis of variance, BMI = body mass index, CVD = cardiovascular diseases, HPA = Health Promotion Administration, ICD-9-CM = International Classification of Diseases, MOST = Ministry of Science and Technology, NHIRD = National Health Insurance Research Database, Ninth Revision, Clinical Modification code, PA = physical activity, T2DM = type-2 diabetes mellitus,.

Keywords: diabetes mellitus, exercise, health care costs, physical activity

1. Introduction

Diabetes mellitus (DM) remains a major public health issue. The global prevalence was predicted at 2.8% in 2000 and 4.4% in 2030.[24] The economic burden of diabetes has increased over time with disease severity.[28] It is becoming more expensive to treat the disease and its related complications.[8] The estimated cost of DM in the United States grew from $130 billion in 2002 to $245 billion in 2012.[9,15] In the United Kingdom, around 10% of the total health care expenditure was used for diabetic care.[26] In Taiwan, inpatient expenditure for DM increased from 19.3% in 2000 to 26.4% in 2009.[33] Reducing the prevalence of DM could improve health-related quality of life and can also lower economic or health care spending.

Physical inactivity has adverse effects on health and is directly responsible for the high cost of medication.[18] Of the total health

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care cost in Canada, costs associated with physical inactivity and obesity represented 2.6% and 2.2%, respectively.[10] Findings from another study showed that inactive compared with active Brazilians were associated with a higher health care cost (US $241.06 vs US$94.11). Moreover, expenditures related to DM were significantly higher in the inactive group (US$65.14 vs US $14.68).

According to Bruna and his team, prevention of higher health care costs associated with diseases including DM depends essentially on the promotion of healthy habits.[19] Meeting the recommended levels of physical activity (PA, i.e., 150 minutes/week)[21] is essential for mitigating health care costs. Results from a previous study showed that participants with and without established cardiovascular diseases (CVDs) who were engaged in moderate-vigorous physical activity registered lower health care costs and resource utilization.[36] Regular PA has been inversely associated with the risk of DM.[27] Findings from a meta-analysis showed that habitual leisure-time PA decreased glycated hemoglobin A1c (HbA1c) level and lowered the health care expenditure of patients with DM.[2] The effects are similar to those of dietary, drug, and insulin treatments.[34] According to investigations by Trust for America's Health, only putting $10 per person per year into improving programs about physical inactivity, poor nutrition, and smoking will save more than $16 billion medical costs in 5 years.[4] Moreover, a shred of sound scientific evidence is needed to stimulate health awareness among citizens. Previous studies to investigate the effects of PA on medical costs have made use of small sample sizes. Therefore, this study aimed to assess the relationship between PA and medical expenditures in patients with DM using multiple national databases.

2. Methods

Data used in this study were collected from 3 national databases that were linked using personal identification numbers. Data on DM were obtained from the National Health Insurance Research Database (NHIRD). Data on physical exercise were obtained from the National Adult Preventive Medical Services Database, while mortality data were obtained from the Death Registry Database. All personal information contained in the databases was de-identified for privacy reasons. The central regional research ethics committee of Taiwan (CRREC-104-015) approved this study.

The National Health Insurance (NHI) was set up in 1995 to gather information on the health of Taiwan citizens. The coverage rate is currently about 99%. The Health Promotion Administration (HPA) launched free preventive care services for adults in 1996. Services are offered free of charge once every 3 years to people aged 40 to 64 years and once every year to those over the age of 65. About 1.704 million individuals are reported to have received the services in 2008. The medical services include physical examination, blood, and urine tests, as well as health consultations.[7,25]

We assessed historical data of 1,572,930 male and female participants aged 40 years and older who were engaged in adult preventive health services in 2012. Of these participants, 249,114 persons were identified with DM. However, patients who died before 2013 (n=3553) and those with incomplete information (n=26,601) were excluded. Included in the final analysis were 218,960 patients. DM was diagnosed based on the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) code 250. Patients were defined as those who had at least 2 ambulatory claims or 1 inpatient claim in 2011. PA was measured based on self-report and was categorized as no exercise (physically inactive), exercise less than 150 minutes per week (insufficiently active), and exercise more than 150 minutes per week (sufficiently active) within the last 3 months. Sociodemographic characteristics included age, gender, body mass index (BMI) measured in kg/m^2, glucose levels (mg/dL), medical expenditure, Charlson Comorbidity Index (CCI) score ($\leq$2, 3–4, $\geq$5),[22] smoking (never, occasional, and frequent), drinking (never, occasional, and frequent), betel nut use (never, occasional, and frequent), total cholesterol (mg/dL), triglycerides (mg/dL), high-density lipoprotein (mg/dL), low-density lipoprotein (mg/dL), systolic blood pressure (mm Hg), and diastolic blood pressure (mm Hg). Betel nut was relevant in the analysis because of its previously reported associations with T2DM in Taiwan.[11,32] It is common in South East Asia[3] and its major alkaloid is believed to interfere with insulin-induced glucose uptake.[14] Medical expenditure included the total amount [in American Dollars (US$)] of each disbursement (inpatient and outpatient care service) in 2013. The total annual costs were calculated by finding the sum of all outpatient and inpatient services and medical prescriptions.

2.1. Statistical analysis

A Chi-square test was used for the categorical variables. Continuous variables were expressed as mean ± standard error (SE). Multivariate linear regression models were used to determine the β-coefficients and their *P* values. Comparisons of continuous data among the 3 groups (i.e., physically inactive, insufficiently active, and sufficiently active groups) were done using analysis of variance (ANOVA) and post-hoc Tukey test. This study used SAS software (version 9.4, SAS Institute Inc., Cary) as a statistical tool and $P < .05$ was considered statistically significant.

3. Results

There were 218,960 eligible participants in this study (Table 1). Of the general participants, 51.9% were physically inactive, 35% were insufficiently active, and 13.1% were sufficiently active. As summarized in Table 1, health care cost derived from outpatient or inpatient care was significantly lower among sufficiently active than inactive participants ($P < .0001$). The total annual health care cost was significantly lower among sufficiently active (US $755.83) and inadequately active (US$880.08) adults ($P < .0001$) compared with the inactive group (US$1200.01). Lower levels of glucose and higher concentrations of high-density lipoprotein cholesterol (HDL-C) were found among sufficiently active adults when compared with the inactive and insufficiently active groups ($P < .0001$).

Tables 2 and 3 summarize the health care costs attributable to DM in male and female patients according to age, Charlson score, and different levels of PA. No significant differences in health care costs were observed in male and female patients aged 40 to 54 years no matter their CCI score and PA level. Compared with the inactive group, sufficiently and insufficiently active men 55 to 69 years old with CCI score $\geq$5 were associated with a lower annual health care cost by US$864.89 (β=-864.89, $P = .027$) and US$768.20 (β=-768.20, $P = .004$), respectively. Besides, CCI score 3 to 4 was also associated with a lower health care cost by US$105.27 among insufficiently active adults and US

Table 1

Baseline characteristics of patients with DM stratified by physical activity level.

	Inactive n=113,544	Insufficiently active n=76,761	Sufficiently active n=28,655	P
Gender, n (%)				<.0001
Men	47,979 (42.26)	35,527 (46.28)	14,669 (51.19)	
Women	65,565 (57.74)	41,234 (53.72)	13,986 (48.81)	
Age, n (%)				<.0001
40–54 y	15,179 (13.37)	8664 (11.29)	2320 (8.10)	
55–69 y	44,254 (38.98)	32,957 (42.93)	12,313 (42.97)	
≥70 y	54,111 (47.66)	35,140 (45.78)	14,022 (48.93)	
BMI n (%)				<.0001
BMI <18.5 kg/m^2	2727 (2.40)	1042 (1.36)	365 (1.27)	
18.5≤BMI<24 kg/m^2	36,236 (31.91)	24,448 (31.85)	10,043 (35.05)	
24≤BMI<27 kg/m^2	35,255 (31.05)	25,602 (33.35)	9843 (34.35)	
BMI≥27 kg/m^2	39,326 (34.64)	25,669 (33.44)	8404 (29.33)	
CCI, n (%)				<.0001
≤2	79,426 (69.95)	56,469 (73.56)	21,164 (73.86)	
3–4	25,780 (22.70)	16,011 (20.86)	6068 (21.18)	
≥5	8338 (7.34)	4281 (5.58)	1423 (4.97)	
Total expenditure (US$, mean±SE)*	1200.01±3.56	880.08±3.18	755.83±4.47	<.0001†,‡,§
Outpatient expenditure (US$, mean±SE)*	140.16±0.42	133.28±0.48	130.72±0.77	<.0001†,‡
Inpatient expenditure (US$, mean±SE)*	1059.85±3.15	746.80±2.70	625.11±3.69	<.0001†,‡,§
Smoking, n (%)				<.0001
Never	102,758 (90.50)	68,488 (89.22)	26,236 (91.56)	
Occasional	2404 (2.12)	2248 (2.93)	552 (1.93)	
<1 pack/d	5339 (4.70)	4263 (5.55)	1393 (4.86)	
≥1 pack/d	3043 (2.68)	1762 (2.30)	474 (1.65)	
Drinking, n (%)				<.0001
Never	103,007 (90.72)	66,618 (86.79)	24,594 (85.83)	
Occasional	8229 (7.25)	8620 (11.23)	3552 (12.40)	
Frequent	2308 (2.03)	1523 (1.98)	509 (1.78)	
Betel nut, n (%)				<.0001
Never	109,088 (96.08)	74,221 (96.69)	28,114 (98.11)	
Occasional	2428 (2.14)	1586 (2.07)	367 (1.28)	
Frequent	2028 (1.79)	954 (1.24)	174 (0.61)	
Laboratory tests (mean±SE)*				
Cholesterol, mg/dL	187.86±0.56	187.63±0.68	185.65±1.10	<.0001‡,§
Triglyceride, mg/dL	158.92±0.47	150.05±0.55	139.91±0.83	<.0001†,‡,§
HDL-C (mg/dl)	48.80±0.14	49.70±0.18	50.66±0.30	<.0001†,‡,§
LDL-C, mg/dL	111.03±0.33	112.37±0.41	113.32±0.67	<.0001†,‡
Glucose, mg/dL	148.09±0.44	144.26±0.52	138.01±0.82	<.0001†,‡,§
SBP, mm Hg	135.12±0.40	135.75±0.49	135.31±0.80	<.0001†,§
DBP, mm Hg	78.48±0.23	78.31±0.28	77.53±0.46	<.0001†,‡,§

Physical activity was classified as no exercise (inactive group); exercise <150 min/wk (insufficiently active), and exercise >150 minutes/wk (active).

BMI=body mass index, CCI=Charlson comorbidity index, DBP=diastolic blood pressure, HDL-C=high-density lipoprotein cholesterol, LDL-C= low-density lipoprotein cholesterol, SBP=systolic blood pressure, USD=United States Dollar.

* Data are presented as mean±standard error (SE).

† Means±SE are significantly different between inactive and insufficiently active individuals.

‡ Means±SE are statistically significant between inactive and sufficiently active individuals.

§ Means±SE are statistically significant between insufficiently active and active individuals.

Table 2

Health care expenditures of male patients based on physical activity, age, and Charlson score.

				Insufficiently active		Sufficiently active	
Age	CCI	n	Inactive*	β	P	β	P
40–54 y	≤2	12,181	ref	−62.88	.102	−93.27	.139
	3–4	1984	ref	−5.06	.980	260.01	.389
	≥5	394	ref	−365.95	.556	557.18	.594
55–69 y	≤2	29,227	ref	−46.55	.125	−45.01	.268
	3–4	7894	ref	−105.27	.269	−223.56	.090
	≥5	2098	ref	−768.20	.004†	−864.89	.027†
≥70 y	≤2	27,084	ref	−26.23	.560	−16.01	.781
	3–4	12,406	ref	−191.74	.025†	−240.66	.030†
	≥5	4907	ref	−364.49	.045†	−395.98	.123

Participants were classified into 3 exercise intervention groups: no exercise (inactive group); exercise <150 min/wk (insufficiently active group), and exercise >150 min/wk (sufficiently active group) groups. Adjusted for smoking, drinking, betel nut chewing, systolic blood pressure, diastolic blood pressure, cholesterol, triglyceride, HDL-C, LDL-C, glucose, BMI, and cost type (outpatient, inpatient, or both cost).

* Inactive group is the reference.

† Statistically significant results.

Table 3

Health care expenditures of female patients based on physical activity, age, and Charlson score.

Age	CCI	n	Inactive*	Insufficiently active		Sufficiently active	
				β	*P*	β	*P*
40–54 y	≤2	9798	ref	−4.12	.918	37.50	.581
	3–4	1561	ref	−0.50	.997	−55.97	.823
	≥5	245	ref	−744.44	.132	−506.03	.616
55–69 y	≤2	38,581	ref	−18.60	.410	−50.92	.117
	3–4	9565	ref	−119.56	.040*	−26.26	.756
	≥5	2159	ref	−293.03	.115	−193.05	.518
≥70 y	≤2	40,188	ref	8.92	.768	−98.18	.025*
	3–4	14,449	ref	−39.03	.584	−154.12	.160
	≥5	4239	ref	−302.35	.094	−497.20	.096

Participants were classified into 3 exercise intervention groups: no exercise (inactive); exercise <150 min/wk (insufficiently active), and exercise >150 min/wk (active) groups.
Inactive group is the reference.
Adjusted for smoking, drinking, betel nut chewing, systolic blood pressure, diastolic blood pressure, cholesterol, triglyceride, HDL-C, LDL-C, glucose, BMI, and cost type (outpatient, inpatient, or both).
CCI = Charlson comorbidity index, ref = reference.
* Statistically significant results.

$ 223.56 among sufficiently active adults even though it was not significant. Moreover, the lower health care cost in men ≥70 years with CCI score 3 to 4 was by US$191.74 (β = -191.74, *P* = .025) among insufficiently active adults, and US$240.66 (β = -240.66, *P* = .030) among sufficiently active adults, while those with score ≥5 was by US$ 364.49 (β = -364.49, *P* = .045) and US$395.98 (β = -395.98, *P* = .123), respectively.

No significant differences in health care costs were observed in women belonging to the 40 to 54 and 55 to 69 age category. Compared with inactive women ≥70 years old, sufficiently active women were associated with a lower health care cost even though the results were significant only for CCI score ≤2 (β = -98.18, *P* = .025).

4. Discussion

This is the first cross-sectional study to estimate the annual health care spending associated with DM among active and inactive Taiwanese adults. Our analysis indicated that sufficiently active diabetic patients (i.e., those who exercised more than 150 minutes per week) were associated with lower health care costs (i.e., US $755.83) followed by insufficiently active patients (US$880.08) when compared with their inactive counterparts (US$1200.01). Associations between PA and lower costs linked to DM have also been reported in Western populations.[9,12] Findings from another study suggested that inactive individuals had an 11.1% increase in aggregate health care expenditure compared with an active group.[17] Our findings also share a number of similarities with recent findings, where higher fitness was associated with lower health care costs, which was more obvious among patients with diabetes.[30] That is, after adjusting for potential variables, the mean annual costs per patient over an 8-year period were found to be US$32178 lower among patients in the highest-fit than those in the least-fit category. In another study to assess a 10-year cost-effectiveness of lifestyle intervention and metformin for diabetes prevention, the Diabetes Prevention Program Research group observed a 17% relative reduction in inpatient health care costs in the lifestyle intervention group.[16]

The prevalence of DM in Taiwan is from 4.9% to 9.2%.[1] We observed that the prevalence of the disease among inactive participants was relatively high (i.e., 51.9%). On the basis of findings from previous studies, physical inactivity is a potentially important risk factor for diabetes.[13,31,29] It appears to have a direct effect on diabetes risk[31] and also serves as a predictor of mortality in men with DM.[29] According to reports by the International Diabetes Federation, over 1,958,000 cases (10.9%) of diabetes were reported among Taiwanese adults in 2017. The disease prevalence is likely to increase in the coming years considering that it is the fastest-growing chronic disease in the world.[5] However, our findings suggest that about 330 to 660 million USD (10–20 billion NTD) could be saved annually if Taiwanese adults with DM could adopt a more active lifestyle.

The percentage of adults with diabetes increase with age,[6] as does the risk of comorbidity. Besides, the cost of diabetes is known to be higher for patients with comorbid illness.[23] In light of this, our stratified analysis was based on age (40–54, 55–69, ≥70 years) and CCI score (≤2, 3–4, ≥5). It is reasonable for elderly patients with more comorbidities to experience a rise in medical expenditure.[20] On the basis of stratification by PA, we found that the effect of comorbidity on health care costs associated with DM was significant only in the ≥70 and 55 to 69 age categories of men. That is, compared with the inactive group, 55 to 69-year-old sufficiently and insufficiently active men with CCI score ≥5 were associated with a lower annual health care cost by US$864.89 and US$768.20, respectively. Likewise, the lower costs were US$240.66 and US$191.74 among sufficiently active and insufficiently active men ≥70 years old with CCI score 3 to 4.

Some limitations of our study are worth noting. First, the study sample is limited to patients who were engaged in adult preventive health services that are restricted to adults aged 40 years and older. Therefore, we could not determine medical costs for Taiwanese patients younger than 40. Second, medical spending of DM patients with both microvascular and macrovascular complications is 4 times higher than those without complication.[35] Such information was not available in our databases. However, we adjusted for potential variables and costs were stratified based on Charlson comorbidity scores. Of note, including covariates in the model is not a cure for selection bias or reverse causality, for both forms of bias may be present in our data. Therefore, our results may not generalize to other populations. Third, medical costs may have been underestimated, as they did not include self-paid items or health supplements. Fourth, databases used in our study provided no information about activity patterns. Moreover, the amount of PA, transportation cost, and occupational activities may have been overestimated.

5. Conclusion

Compared with being sedentary, PA even below recommended levels was associated with lower health care expenditures of Taiwanese adults with type 2 DM. These findings highlight the importance of habitual PA in minimizing the burden imposed by diabetes. Future studies with both young and old adults will be necessary to validate our findings in other populations globally.

Author contributions

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