Current Medical Science
DOI https://doi.org/10.1007/s11596-019-2063-x 39(3):483-492,2019

Effect of Physical Activity on Hospital Service Use and Expenditures of Patients with Coronary Heart Disease: Results from Dongfeng-Tongji Cohort Study in China*

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Summary: The intervention of behaviors, including physical activity (PA), has become a strategy for many hospitals dealing with patients with chronic diseases. Given the limited evidence available about PA and healthcare use with chronic diseases, this study explored the association between different levels of PA and annual hospital service use and expenditure for inpatients with coronary heart disease (CHD) in China. We analyzed PA information from the first follow-up survey (2013) of the Dongfeng-Tongji cohort study of 1460 CHD inpatients. We examined factors such as PA exercise volume and years of PA and their associations with the number of inpatient visits, number of hospital days, and inpatient costs and total medical costs. We found that the number of hospital days and the number of inpatient visits were negatively associated with intensity of PA level. Similarly, total inpatient and outpatient costs declined when the PA exercise volume levels increased. Furthermore, there were also significant associations between the number of hospital days, inpatient costs or total medical costs and levels of PA years. This study provides the first empirical evidence about the effects of the intensity and years of PA on hospital service use and expenditure of CHD in China. It suggests that the patients' PA, especially the vigorous PA, should be promoted widely to the public and patients in order to relieve the financial burden of CHD.
Key words: physical activity; coronary heart disease; hospital service use; healthcare expenditure

Regular physical activity (PA) has been found to be associated with a lower risk of the morbidity and mortality for many chronic diseases, including cardiovascular diseases (CVDs) and cancer[1–5]. Although there are many studies on PA and CVDs, most of them focus on morbidity and mortality. There has been very little research reported on health care use and expenditure between incidence and death. As a chronic disease, illness related to CVDs has a long duration, which would increase expenditure on basic and long-term care. In the United States, the health care costs of coronary heart disease (CHD), diabetes and obesity are nearly half a trillion dollars[6]. Although physical inactivity has been shown to be positively associated with health care use, the literature in this area is quite limited, especially for the separate estimates of the associations of PA and health care use and expenditure for CVDs[7–10].

During recent decades, the prevalence of chronic diseases has increased significantly worldwide, which places considerable strain on the health care system[11–14]. In particular, CVDs, including hypertension, CHD, and stroke, may be some of the main chronic diseases related to increased health care expenditure[15, 16]. There is a growing interest from policymakers in the potential role of PA as a strategy to take on these challenges, especially in developing countries[17, 18]. According to estimates from Global Burden of Disease (GBD) 2017, the incidence rate per 100 000 persons of all ages from

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*This work was supported by China Medical Board and the Fundamental Research Funds for the Central Universities, HUST (No. 2015XJGH014).

CVDs in China were 958.64 (920.61 to 999.65), while the mortality per 100 000 were 309.95 (299.66 to 319.80). In 2017, 4.4 million and 17.8 million CVD-related deaths occurred in China and globally, making it the leading cause of deaths in China and globally[19, 20]. The rapid growth of the ageing population in China and the number of patients with CVDs have brought great challenges to China's health care system[21, 22]. To date, no published studies have analyzed the relations between PA, health care use and expenditure for patients with CVDs or other chronic diseases in China.

Given the limited evidence available, empirical data examining the associations between PA and health care use or expenditure among patients with CVDs are greatly needed. This cross-sectional study aims to analyze the associations between different levels of PA and 1-year hospital service use and expenditure for patients with CHD based on data from the Dongfeng-Tongji (DFTJ) cohort study in China.

1 SUBJECTS AND METHODS

1.1 Study Design and Participants

Data for our study were drawn from the DFTJ cohort study, which was initiated in 2008 among Dongfeng Motor Corporation (DMC) retirees[23]. DMC was founded in 1969 as one of the three largest state-owned auto manufactures in China. Most first-generation employees are now retired and reside in three cities, Shiyan, Wuhan, and Xiangyang, which are DMC's three major industrial bases in Hubei Province in central China. All retired DMC employees are covered by the DMC Retirement Office and Medical Insurance Center. A list of retired company employees was provided by DMC and they were invited to participate in DFTJ cohort study. In total, 31 000 retired DMC employees were included in the study. Between September 2008 and June 2010, 87.0% of retired employees (27 009 of 31 000) completed baseline questionnaires, medical examinations, and provided baseline blood samples. Trained interviewers administered a semi-structured questionnaire to collect data including demographic information, family and personal disease histories, drug use, lifestyle, and PA during face-to-face interviews of the cohort.

The socio-demographic characteristics and PA information of the participants in our study came from the first follow-up survey (2013) of the cohort study, whilst hospital service use and expenditure information in 2013 came from the DMC affiliated medical insurance system.

In the present study, we limited our sample to patients with CHD who had inpatient hospital experiences due to CHD in 2013. Of the 1481 eligible participants (27.50%, 1481 of 5385), 21 cases were excluded because of missing data for independent variables. The final sample included 1460 observations (27.11%, 1460 of 5385). The details of the diagnostic criteria of CHD were described in a previous report[24]. In short, the diagnosis of CHD including stable angina (SA), unstable angina (UA), non-fatal myocardial infarction (non-fatal MI) and unspecified CHD was based on well-accepted international standards by cardiologists in the DMC-owned hospitals. SA was defined as angina with no change in frequency, duration, or intensity of symptoms in 6 weeks. UA was defined as angina at rest, accelerated angina or new onset of severe angina. Non-fatal MI was diagnosed based on typical symptoms, ECG change, and cardiac enzyme values[25].

Ethical approval of this study was granted by the Medical Ethics Committee of School of Public Health, Tongji Medical College, Huazhong University of Science and Technology and DMC affiliated Dongfeng General Hospital. Written informed consent was obtained from all participants before data collection.

1.2 Measures

1.2.1 Independent Variables PA was assessed by the question "In the past year, did you participate in the following physical activities?" Response options were No (almost no exercise, or occasionally exercise but less than once a month) and Yes. If "Yes" was chosen, the frequency (how many times per week) and average duration (how many minutes per time) of different types of PA were investigated. Activities included walking, jogging, biking, playing ball games, dancing, tai chi, swimming, exercising at the gym, and others. To estimate the total energy expenditure for each individual, metabolic equivalent (MET) hours per week were calculated for each activity according to the formula, MET coefficient of activity × duration (hours per time) × frequency (times per week). MET coefficients used for leisure activities were: 3 for walking, 4 for biking, 4.5 for tai chi, 5 for dancing or calisthenics, 6 for playing ball games or exercising in a gym, 7.5 for jogging and swimming[26, 27]. Previous studies have shown that PA might change the status of health as well as health service use, similar to how "quantitative accumulation (PA exercise volume) could lead to qualitative transformation (health status as well as health service use)."[7–10]. Therefore, the next question concerns the level of quantitative accumulation that leads to qualitative transformation. Specifically, what level of PA exercise volume would lead to a change in health status and health service use? Here, we used the MET-h/week as a categorical variable, and divided the PA level into four groups according to its distribution: 0 (no activity), ≤18.0 (light activity), 18.01–36.0 (moderate activity), and ≥36.01 (vigorous activity) MET-h/week.

Additionally, we also obtained long-term physical activity (years of PA) information by asking those people who did exercise, "Up to now, how many years have you participated in physical activity?" In the current study, years of PA was classified at four levels: 0 years (never), 1–4 years, 5–9 years and ≥10 years.

1.2.2 Dependent Variables The dependent variables in this study were each individual's 2013 number of inpatient visits, number of hospital days, and inpatient costs and outpatient costs in RMB based on medical records from the DMC affiliated medical insurance system. All retired employees were covered by DMC's health-care service system and each participant had a unique medical insurance card number and ID, which enabled the researchers to track the records of participants' information related to their hospital service use and expenditure.

1.2.3 Covariates Covariates from the cohort study questionnaires included: age (<65, ≥65 years), sex (men, women), marital status (married, remarried, single, widowed and divorced), educational level (primary school or illiteracy, middle school, high school, and university/college or higher), smoking status (current smoker, ex-smoker and nonsmoker), drinking status (current drinker, ex-drinker and nondrinker), and comorbidity of self-reported hypertension, hyperlipidemia or diabetes mellitus (0,1, ≥2).

1.3 Statistical Analysis

Descriptive analysis was carried out for the primary variables, with continuous variables expressed in means±standard deviation (SD) and categorical variables presented in percentages. Chi squared tests were used to examine the significance level of the associations between categorical variables. Because continuous variables of inpatient and outpatient costs showed a positively skewed distribution, medians and quartiles were also indicated. Using logistic regression analysis, we calculated odds ratios (ORs) and 95% confidence intervals (95%CI) to assess the association between the intensity and years of PA and the number of inpatient visits. General linear modeling (GLM) was used to assess the correlations between PA and the total number of hospital days and costs. Owing to the positively skewed distribution of patient costs data, these data were log-transformed. Estimates of the correlation coefficient (β) and 95%CI were calculated. Four adjusted models were calculated for each of these regressions: Model 1 included the intensity or years of PA only; Model 2 added age, sex, education level and marital status; Model 3 added smoking and drinking status; and Model 4 added associated comorbidity status, i.e., self-reported hypertension, hyperlipidemia or diabetes mellitus. A two-sided P value of <5% was used to determine statistical significance. Statistical calculations were performed using the Statistical Package for Social Sciences Version 12.0 (SPSS Inc., USA) for Windows.

2 RESULTS

Table 1 shows the general characteristics of the study population. Of the 1460 participants, 53.6% were women, 68.1% were older than 65 years, and 15.4% were single, divorced or widowed. Only 191 (13.1%) individuals reported no PA, whilst 27.2% and 30.1% reported vigorous and moderate levels of PA respectively. The majority of participants (60.4%) reported over 10 years of PA experiences. PA exercise volume was higher in men than in women (vigorous level: 31.31% *vs.* 23.63%). However, the difference between age (<65 years and ≥65 years old) and PA exercise volume was not statistically significant. Interestingly, gender and age difference among the intensity of PA was converse with those of the years of PA. In addition, among participants aged 65 years or above, 65.22% had a PA history for more than 10 years.

Table 2 presents the distributions of hospital service use and expenditure in 2013 by levels of exercise volume and years of PA. Participants with no PA were more likely to have more inpatient visits, longer hospital days, and greater patient costs. Hospital days decreased by PA exercise volume level from no activity, light, moderate to vigorous, i.e., 18.91±18.03, 15.54±13.89, 15.62±12.65, and 14.50±12.77 respectively. Similarly, total inpatient and outpatient costs declined with the PA exercise volume levels from no activity, light, moderate and vigorous, i.e., 23.08±27.78, 16.78±21.52, 18.50±22.59, and 17.42±21.48 thousand RMB. The distributions of hospital service use and expenditure by levels of PA exercise volume were very similar to those of levels of PA years.

Table 3 shows the association between the exercise volume and years of PA with hospital service use and expenditure of CHD patients. In the unadjusted logistic regression model, people with vigorous PA had significantly lower probability of receiving hospital service use (OR 0.50, 95% CI: 0.33–0.75), and the association was almost unchanged when adjusted for the covariates from Model 1 to Model 4. In the unadjusted general liner model, people with no activity had significantly longer hospital days, greater inpatient costs and outpatient costs. When adjusted for the covariates, although the significance of difference had some changes, the association with vigorous PA remained highest. The results of these three outcome variables were similar. Furthermore, apart from the number of hospitalizations, the association of hospital service use and expenditure by levels of the PA exercise volume was very similar to that by levels of PA years.

3 DISCUSSION

To our knowledge, this study provides the first

Table 1 Patient characteristics of primary variables by levels of physical activity

	Overall	Intensity of physical activity						Years of physical activity					
	n (%)	No activity *n* (%)	Light *n* (%)	Moderate *n* (%)	Vigorous *n* (%)	χ^2/F	*P*	0 *n* (%)	1–4 *n* (%)	5–9 *n* (%)	≥10 *n* (%)	χ^2/F	*P*
Total	1460 (100.00)	191 (13.10)	433 (29.70)	439 (30.10)	397 (27.20)			191 (13.10)	174 (12.00)	211 (14.50)	878 (60.40)		
Sex													
Men	677 (46.37)	74 (10.93)	193 (28.51)	198 (29.25)	212 (31.31)	13.204	0.004	74 (10.95)	83 (12.28)	97 (14.35)	422 (62.43)	5.607	0.132
Women	783 (53.63)	117 (14.94)	240 (30.65)	241 (30.78)	185 (23.63)			117 (15.04)	91 (11.70)	114 (14.65)	456 (58.61)		
Age													
<65 years old	466 (31.92)	50 (10.73)	135 (28.97)	146 (31.33)	135 (28.97)	0.244	0.062	50 (10.82)	73 (15.80)	108 (23.38)	231 (50.00)	59.843	0.000
≥65 years old	994 (68.08)	141 (14.19)	298 (29.98)	293 (29.48)	262 (26.36)			141 (14.21)	101 (10.18)	103 (10.38)	647 (65.22)		
Educational level													
Primary or illiteracy	415 (28.78)	63 (15.18)	111 (26.75)	136 (32.77)	105 (25.30)	9.093	0.429	63 (15.22)	39 (9.42)	60 (14.49)	252 (60.87)	8.989	0.438
Middle school	538 (37.31)	73 (13.57)	152 (28.25)	159 (29.55)	154 (28.62)			73 (13.57)	74 (13.75)	82 (15.24)	309 (57.43)		
High school	347 (24.06)	39 (11.24)	108 (31.12)	102 (29.39)	98 (28.24)			39 (11.24)	40 (11.53)	47 (13.54)	221 (63.69)		
University or high	142 (9.85)	16 (11.27)	51 (35.92)	38 (26.76)	37 (26.06)			16 (11.27)	19 (13.38)	18 (12.68)	89 (62.68)		
Marital status													
Married/remarried	1228 (84.63)	150 (12.21)	368 (29.97)	370 (30.13)	340 (27.69)	5.390	0.145	150 (12.22)	154 (12.55)	182 (14.83)	741 (60.39)	6.464	0.091
Single/widow/divorce	223 (15.37)	39 (17.49)	58 (26.01)	69 (30.94)	57 (25.56)			39 (17.49)	20 (8.97)	29 (13.00)	135 (60.54)		
Smoking status													
Nonsmoker	980 (67.59)	135 (13.78)	297 (30.31)	300 (30.61)	248 (25.31)	13.110	0.041	135 (13.79)	112 (11.44)	143 (14.61)	589 (60.16)	1.936	0.926
Ex-smoker	264 (18.21)	30 (11.36)	73 (27.65)	67 (25.38)	94 (35.61)			30 (11.36)	34 (12.88)	37 (14.02)	163 (61.74)		
Current smoker	206 (14.21)	25 (12.14)	58 (28.16)	70 (33.98)	53 (25.73)			25 (12.14)	27 (13.11)	31 (15.05)	123 (59.71)		
Drinking status													
Nondrinker	1056 (72.78)	155 (14.68)	317 (30.02)	316 (29.92)	268 (25.38)	13.987	0.030	155 (14.69)	118 (11.18)	150 (14.22)	632 (59.91)	15.646	0.016
Ex-drinker	143 (9.86)	16 (11.19)	39 (27.27)	44 (30.77)	44 (30.77)			16 (11.19)	14 (9.79)	17 (11.89)	96 (67.13)		
Current drinker	252 (17.37)	20 (7.94)	70 (27.78)	77 (30.56)	85 (33.73)			20 (7.94)	41 (16.27)	43 (17.06)	148 (58.73)		
Co- morbidity (self-reported)													
0	387 (26.91)	49 (12.66)	106 (27.39)	118 (30.49)	114 (29.46)	11.617	0.071	49 (12.66)	44 (11.37)	52 (13.44)	242 (62.53)	1.507	0.959
1	527 (36.65)	67 (12.71)	142 (26.94)	156 (29.60)	162 (30.74)			67 (12.71)	63 (11.95)	80 (15.18)	317 (60.15)		
2–3	524 (36.44)	74 (14.12)	172 (32.82)	160 (30.53)	118 (22.52)			74 (14.15)	63 (12.05)	76 (14.53)	310 (59.27)		

Table 2 Hospital service use and expenditure by levels of physical activity

	Overall	Intensity of physical activity						Years of physical activity					
	n (%)	No activity *n* (%)	Light *n* (%)	Moderate *n* (%)	Vigorous *n* (%)	χ^2/F	*P*	0 *n* (%)	1–4 *n* (%)	5–9 *n* (%)	≥10 *n* (%)	χ^2/F	*P*
Annual number of inpatient visits													
1	1118 (76.58)	133 (11.90)	332 (29.70)	327 (29.25)	326 (29.16)	12.995	0.005	133 (11.95)	140 (12.58)	174 (15.63)	666 (59.84)	10.919	0.012
≥2	342 (23.42)	58 (16.96)	101 (29.53)	112 (32.75)	71 (20.76)			58 (17.01)	34 (9.97)	37 (10.85)	212 (62.17)		
Annual number of hospital days													
Mean±SD	1460	18.91±18.03	15.54±13.89	15.62±12.65	14.50±12.77	4.413	0.004	18.91±18.03	14.41±12.47	13.82±11.70	15.78±13.57	5.210	0.001
Median (Q1–Q3)		13.00 (8.00–23.00)	10.00 (7.00–18.00)	12.00 (8.00–19.00)	10.00 (7.00–17.50)	4.380	0.112	13.00 (8.00–23.00)	10.00 (7.00–16.00)	10.00 (7.00–16.00)	11.50 (7.00–19.00)	7.591	0.022
Annual inpatient costs (thousand RMB)													
Mean±SD	1460	21.00±26.37	15.88±21.11	17.49±22.12	16.46±20.99	2.564	0.053	21.00±26.37	15.30±20.15	17.83±22.88	16.59±21.33	2.583	0.052
Median (Q1–Q3)		10.23 (6.64–24.02)	8.86 (5.43–13.82)	8.75 (5.88–15.69)	8.58 (5.39–14.26)	2.071	0.355	10.23 (6.64–24.02)	8.52 (4.88–13.41)	8.71 (5.81–14.49)	8.75 (5.64–14.54)	1.816	0.403
Annual inpatient and outpatient costs (thousand RMB)													
Mean±SD	1460	23.08±27.78	16.78±21.52	18.50±22.59	17.42±21.48	3.667	0.012	23.08±27.78	16.13±20.49	18.82±23.52	17.57±21.77	3.674	0.012
Median (Q1–Q3)		11.88 (7.36–27.16)	9.61 (5.83–15.58)	9.79 (6.05–18.04)	9.34 (5.64–15.25)	1.826	0.401	11.88 (7.36–27.16)	9.39 (4.95–15.56)	9.00 (6.06–17.07)	9.79 (6.02–15.84)	2.265	0.322

empirical evidence about the effects of the intensity and years of PA on hospital service use and expenditure of CHD in China. The findings indicate that for older adults suffering from CHD, higher PA exercise volume is associated with lower hospital service use and expenditure. Similarly, longer years of PA participation are associated with lower hospital service use and expenditure.

Although there are differences in the study populations, methods, and measures, the findings of our study are in line with a number of previous studies with similar outcome variables[28–30]. For example, Sari *et al* examined the association between leisure time PA and the demand for hospital services in older adults and found PA to be inversely associated with hospital stays. Similarly, Woolcott *et al* reported that physically inactive older adults spent about three times annual hospital days in the past year compared with their active counterparts[31]. In addition, several studies that focused on general populations and health care expenditure reported similar results to ours[32, 33]. Current studies have two significant limitations in study design. Firstly, the sample is limited to older adults with CHD who had inpatient hospital experiences rather than the general population or older adults in general. Secondly, most outcome variables, especially the number of inpatient visits and days of hospitalization, are self-reported in the existing studies. In contrast, all outcome variables in our study are from hospital billing records, which would be more accurate than self-reported information. Therefore, this study provides new reliable evidence to support the association between PA and health care use and expenditures.

There are at least two possible explanations for PA's influence on health care use and expenditure. One is the physiological pathway. Regular participation in PA acts on different biologic pathways, including decreasing oxidative stress, increasing nitric oxide release, the clearing of fat free acids and physiological processes associated with a decrease in the risk for arterial hypertension and dyslipidemia. Among individuals with CHD, higher level of PA is inversely related to blood pressure, body fat, uric acid and total cholesterol[30, 33–35]. The other is the psychological pathway. In general, individuals with chronic diseases are at more risk of mental disorder. For individuals with CHD, PA may reduce health care use and expenditure by improving emotional well-being via increases in beta endorphins, the availability of brain neurotransmitters (e.g. serotonin) and self-efficacy[30, 36, 37]. This effect may occur through regular PA helping older adults to continue living in their communities rather than in care homes. Therefore, multiple beneficial effects from PA may be the reason for the decrease in health care use and expenditure. Since previous studies found the association between PA and mortality for CVDs,

Table 3 Association between the intensity and years of physical activity with hospital service use and expenditure of coronary heart disease

	Intensity of physical activity					Years of physical activity				
	No activity (ref)	Light OR/β (95% CI)	Moderate OR/β (95% CI)	Vigorous OR/β (95% CI)	*P*	0 (ref)	1–4 OR/β (95% CI)	5–9 OR/β (95% CI)	≥10 OR/β (95% CI)	*P*
Annual number of inpatient visits										
Model 1	1.00	0.70 (0.48, 1.02)	0.79 (0.54, 1.14)	0.50 (0.33, 0.75)***	0.003	1.00	0.56 (0.34, 0.90)*	0.49 (0.30, 0.78)	0.73 (0.52, 1.03)	0.445
Model 2	1.00	0.75 (0.51, 1.10)	0.81 (0.55, 1.18)	0.52 (0.34, 0.78)**	0.004	1.00	0.61 (0.37, 1.00)	0.54 (0.33, 0.87)	0.74 (0.52, 1.05)	0.356
Model 3	1.00	0.76 (0.51, 1.12)	0.82 (0.56, 1.21)	0.52 (0.34, 0.78)**	0.005	1.00	0.63 (0.38, 1.03)	0.56 (0.34, 0.90)*	0.74 (0.52, 1.06)	0.345
Model 4	1.00	0.76 (0.51, 1.13)	0.81 (0.55, 1.20)	0.52 (0.34, 0.79)**	0.005	1.00	0.63 (0.38,1.05)	0.55 (0.34, 0.90)*	0.75 (0.52, 1.07)	0.355
Annual number of hospital days										
Model 1	0.00	–3.36 (–5.73, –1.00)**	–3.29 (–5.65, –0.93)**	–4.40 (–6.80, –2.01)***	0.002	0.00	–4.50 (–7.35, –1.65)**	–5.09 (–7.81, –2.37)***	–3.12 (–5.30, –0.95)**	0.106
Model 2	0.00	–2.59 (–4.93, –0.24)*	–2.50 (–4.83, –0.17)*	–3.60 (–5.98, –1.23)**	0.011	0.00	–3.43 (–6.26, –0.60)*	–3.58 (–6.30, –0.87)*	–2.61 (–4.75, –0.46)*	0.105
Model 3	0.00	–2.34 (–4.68, 0.00)	–2.13 (–4.46, 0.20)	–3.38 (–5.76, –1.00)**	0.021	0.00	–3.10 (–5.94, –0.27)*	–3.19 (–5.91, –0.48)*	–2.35 (–4.50, –0.21)*	0.138
Model 4	0.00	–2.07 (–4.41, 0.28)	–1.92 (–4.25, 0.40)	–3.07 (–5.45, –0.69)*	0.031	0.00	–2.83 (–5.67, 0.006)	–3.01 (–5.73, –0.29)*	–2.07 (–4.22, 0.07)	0.209
Annual inpatient costs (log-transformed)										
Model 1	0.00	–0.097 (–0.162, –0.031)**	–0.066 (–0.132, –0.001)*	–0.100 (–0.167, –0.034)**	0.046	0.00	–0.121 (–0.201, –0.042)**	–0.075 (–0.151, 0.001)	–0.084 (–0.144, –0.023)**	0.083
Model 2	0.00	–0.084 (–0.150, –0.019)*	–0.058 (–0.123, 0.007)	–0.096 (–0.162, –0.029)**	0.042	0.00	–0.108 (–0.187, –0.029)**	–0.061 (–0.137, 0.015)	–0.077 (–0.137, –0.017)*	0.088
Model 3	0.00	–0.079 (–0.145, –0.014)*	–0.049 (–0.114, 0.016)	–0.090 (–0.157, –0.024)**	0.075	0.00	–0.100 (–0.179, –0.021)*	–0.053 (–0.129, 0.023)	–0.071 (–0.131, –0.011)*	0.108
Model 4	0.00	–0.074 (–0.139, –0.010)*	–0.042 (–0.106, 0.023)	–0.081 (–0.147, –0.015)*	0.132	0.00	–0.096 (–0.174, –0.017)*	–0.046 (–0.121, 0.029)	–0.063 (–0.122, –0.004)*	0.176
Annual inpatient and outpatient costs (log-transformed)										
Model 1	0.00	–0.113 (–0.179, –0.047)**	–0.084 (–0.149, –0.018)*	–0.117 (–0.183, –0.050)**	0.019	0.00	–0.142 (–0.221, –0.062)***	–0.095 (–0.171, –0.019)*	–0.099 (–0.159, –0.038)**	0.042
Model 2	0.00	–0.100 (–0.166, –0.035)**	–0.075 (–0.140, –0.010)*	–0.112 (–0.178, –0.046)**	0.016	0.00	–0.128 (–0.207, –0.049)**	–0.079 (–0.154, –0.003)*	–0.092 (–0.152, –0.032)**	0.040
Model 3	0.00	–0.095 (–0.160, –0.030)**	–0.065 (–0.130, 0.000)	–0.107 (–0.173, –0.040)**	0.033	0.00	–0.119 (–0.198, –0.040)**	–0.070 (–0.145, 0.006)	–0.086 (–0.146, –0.026)**	0.052
Model 4	0.00	–0.091 (–0.156, –0.027)**	–0.058 (–0.122, 0.006)	–0.096 (–0.162, –0.031)**	0.068	0.00	–0.116 (–0.194, –0.038)**	–0.063 (–0.138, 0.012)	–0.078 (–0.137, –0.019)**	0.090

Note: Model 1: intensity and years of PA; Model 2: adjusted for age and sex, educational levels, marital status; Model 3: model 2 plus smoking status, drinking status; Model 4: model 3 plus co–morbidity (self–reported hypertension, hyperlipemia or diabetes occurrence); $^{*}P$<0.05; $^{**}P$<0.01; $^{***}P$<0.001

increased PA would increase the life expectation of the populations and decrease use of health care. In other words, PA is an economical and effective strategy for both developing countries and developed countries to take on the challenges of morbidity, mortality and health resources use from CHD.

Most previous studies about PA and chronic diseases have focused on weekly energy expenditure, weekly frequency, duration (minutes) of PA or intensity combined PA time/minutes, frequency and type, whilst this study takes in account the years of PA[5, 38–40]. As a chronic disease, CHD occurs slowly over time and the progression often takes years. As shown in tables 2 and 3, although the distribution and association of years of PA with hospital service use and expenditure are similar with those of intensity of PA, years of PA and PA exercise volume are two different dimensions, and their distributions are different among participants (table 1). Since our study design cannot compare the levels of importance of these two dimensions, years of PA may be worth examining for future studies related to CHD and other chronic diseases.

Tables 2 and 3 show that the dose-response relationship of PA exercise volume on hospital service use and expenditure is weak, and overall, association of vigorous PA is the largest, and the correlative significance has appeared in all models. Furthermore, the dose-response relationship of years of PA on hospital service use and expenditure does not seem to exist, especially for the association of years of PA with 10 years and above. There are two potential reasons. One may be related to age, especially for those patients with 10 years or more PA experience. The results indicate that there are significant differences between patients under 65 years and those of 65 years and over in the years of PA, and the proportion of participants with 10 years or more PA is the highest (65.22%). As an important risk factor for disease and health care use, age might confuse the dose-response relationship of years of PA for health care use and expenditure, especially for 10 years or more PA. Another reason may be related to PA itself. As a type of behavior, the dose-response relationship of PA might be different from that of biological and chemical factors. For example, individuals who have started exercising for a month may not have strong muscles; however, as exercise continues over the course of a year, muscle strength will be substantially improved. With continuous exercise over 5 or 10 years, muscle strength will stabilize at a certain level, and the improvement might not be significant. Moreover, the increase of age may lead to decrease in muscle strength[41, 42]. A similar phenomenon may exist for the effects of PA on chronic diseases and related issues. It is worth further study to examine differences in the dose-response relationships between PA (as well as other behaviors) and biological and chemical factors.

Among the four outcome variables, the number of hospital days is more suitable than the number of inpatient visits to represent the consumption of health services. It is possible that the number of days in hospital with one inpatient visit is longer than the total number of days for those with two or more inpatient visits. As presented in table 3, the association of PA with number of hospital days is more sensitive and significant than that with the number of inpatient visits. Among the very few studies on health service use for CHD in China, Zhang *et al* used Beijing medical insurance data, with hospital days calculated as the days in one hospital for patients with CHD[43]. However, our study classified hospital days as the days patients were hospitalized due to CHD in a 1-year period. Due to the distribution of non-normal hospital days, Zhang *et al* reported hospital days using geometric mean (geometric mean=9.2 days) that lacks SD and interquartile range data[43]. Another study used a small sample, and also calculated hospital days based on the hospitalization of patients with CHD for one hospital[44]. They found that the mean hospital days of CHD patients with poor nutrition were 17.49±7.01 days (n=41) and those with normal nutrition (n=45) were 12.93±4.37 days. Due to the differences in measurement methods, we are unable to make meaningful comparisons of these two studies with this current study. These previous studies found that the number of hospital days was relatively high. In China, hospital days are generally high for almost all diseases, including hospital delivery[45, 46]. A patient-related explanation is that effective community and home care are generally lacking in China and patients (especially older adults with chronic diseases) tend to spend at least a few days in hospital for each visit. Another explanation is related to health-care providers. In the past 20–30 years, government financial subsidies for public hospitals in China have been inadequate and the vast majority of public hospital income is self-generated, relying heavily on charges for drugs and medical examinations. Therefore, health-care providers may allow patients to have more hospital days than necessary. Additional, the combination of inpatient costs and outpatient costs better reveals the effect of intensity and years of PA on health care expenditure than impatient costs alone, which may be related to the disease characteristics of CHD. As a chronic disease, patients with CHD need longer-term care, and outpatient services are essential.

Despite the well-established benefits of PA, global PA surveillance data show that adults over the age of 60 years are the least active segment of the adult population compared to the younger generations[47–50]. For example, within European Union countries, 80% of respondents aged 65 years and over reported no vigorous PA in the previous week[50]. In contrast, this present study found that over 26% of participants who were older adults suffering from CHD reported vigorous PA. There may be differences in cultural values between the older adults in the west and in China. A shared value among older Chinese adults is that they do not want to burden their children[51]. Sickness among older people may increase not only the economic burden but also, more personally, the time and psychological pressures on family members, which could lead to the need for increased care and companionship from adult children. Therefore, in order not to trouble their children, older Chinese people would consciously adopt healthy lifestyles, including PA. Many older Chinese adults, especially women, would adopt daily collective public exercises such as dancing in public squares which are beneficial for their health[52].

One of the main strengths of this study is related to research measures and methods: this study focused on only one type of disease (CHD); independent variables accounted for the years an individual had been practicing PA, as well as the commonly used intensity of PA; and the four outcome variables are from hospital billing records, which are more accurate than self-reported information. The above differences in study design extend the previous findings about the association between PA and health care use and expenditures. Another strength is related to the sample population, which came from DMC, a state-owned enterprise in China. DMC-affiliated medical insurance covers the cost of primary care received within the system. This allows us to track health care use, disease incidence and mortality through this medical insurance system and Dongfeng Central Hospital, which provides comprehensive care for all active and retired employees. The DMC-affiliated medical insurance system and Dongfeng Central Hospital provide better economic and geographic accessibility, which may reduce the inequalities in health services use due to an individual's socioeconomic status[50, 53, 54].

Nevertheless, the current study has a number of weaknesses. Firstly, self-reported PA measures have some of the inherent limitations such as recall bias[47]. In addition, although all study participants were retired, the retirement age in China is generally young (e.g. 50 for female workers), which leads to the inclusion of younger participants, who might have continued to work temporarily. However, we had no access to data about PA in temporary work. Secondly, participants are from the patients in inpatient hospital services during the previous 12 months, including those with severe illness, which would cause selection bias. Our cross-sectional study could not draw any inferences on causality. It is plausible that healthier people are more prone to be physically active and not that PA leads to better health, and it is also plausible that people with more health care use are not able to be physically active[55]. It is noteworthy that the participants of this study are inpatients who need intense health care and may not have the ability to perform PA. More importantly, even for patients with more serious conditions, PA is effective, which in itself reveals the role of PA. Finally, the cross-sectional design does not offer support for causality statements in the relationship between health care use and expenditures and PA level. As a cohort study, we plan to provide in-depth analysis with follow-up data scheduled in 2018.

In summary, this study provides the first empirical evidence about PA and health care use and expenditure for inpatients with CHD in China. The results indicate that the higher the PA exercise volume (or the longer the years of PA), the less the health care use including hospital service use and expenditure of CHD patients. The considerable financial burden associated with CHD as well as all CVDs could potentially be reduced by increasing the patients' PA, especially the vigorous PA, to take on the challenge with the health care system. In addition, as a behavioral factor, the dose-response relationship of years of PA might be different from that of biological and chemical factors.

Acknowledgments

We thank all study participants and staff of the Health Examination Center of the Dongfeng Central Hospital and the Medical Insurance Center of DMC for their generous help. We also thank the interviewers from the retirement management office of DMC and from Tongji Medical College, HUST. The Dongfeng-Tongji Cohort Study is a collaboration among the Tongji Medical College, Huazhong University of Science and Technology, the DMC and the Harvard School of Public Health.

Conflict of Interest Statement

We declare that we have no conflict of interest.

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(Received May 12, 2017; revised Nov. 30, 2018)