Walking, but not other physical activity at a higher intensity, is associated with improved kidney function: a cross-sectional health survey of general adult population

Running head: ambulation and renal function

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Abstract

Background: Chronic kidney disease is common and brings significant health burden. This study was to investigate the relationship between physical activity and kidney function.

Methods: This was a cross-sectional study set in the Nanjing Community Cardiovascular Risk Survey, using random cluster sampling. Questionnaires were completed, wherever possible, through face-to-face interviews. Age, sex, BMI, weekly physical activity and kidney function were collected. Physical activity was measured by the metabolic equivalent of task × minutes per week, and grouped into “walking”, “moderate” and “vigorous” according to intensity. Kidney function was measured by the estimated glomerular filtration rate (eGFR, mL/min/1.73 m^2). Regression modelling was used to investigate the proposed relationship with adjustment for other confounding factors.

Results: 5,824 participants included, with an average age of 52 years. 44% were males. The eGFR in average was 76, with 19%≥90, 67% between 60-89, and 14%<60. In average the total physical activity during a week was 3,644. Moderate activity contributed 64% of the total activity, followed by walking (23%) and vigorous activity (13%). Overall, the total activity was weakly associated with eGFR ($p=0.039$). However, in stratified analysis, only walking-related activity was associated with eGFR ($p<0.0001$), after confounding adjustment.

Conclusions: Walking is associated with improved kidney function.

Introduction

Chronic kidney disease (CKD) is one of the major health burdens worldwide,[1] with an estimated prevalence more than 10% in the general population.[2-6] It is the progressive deterioration of ability of kidney to remove fluid and nitrogenous waste from the body over a period of months or years. Hypertension and diabetes are the most common risk factors of CKD,[7] and moderate to severe CKD is associated with higher risks of cardiovascular disease (CVD), and CVD-related and all-cause mortality.[8-10] CKD may lead to renal failure (end-stage renal disease), the complete loss of kidney function. When it happens, dialysis or transplant is the only option for those patients.

In order to reduce the disease burden, it is essential to identify modifiable and promotable factors which may help to prevent CKD or the progression of disease. Physical activity has shown to be effective in prevention of certain conditions including hypertension and diabetes.[11,12] However, only a few studies have investigated the relationship between physical activity and CKD or kidney function in the general population, with contradictory findings.[13-15] Physical activity can be divided into various types according to intensity (e.g. low, moderate, vigorous). Whether all physical activity or only a certain subtype plays a role in association with kidney function is unclear.

The purpose of this study was to investigate whether physical activity was associated with kidney function in a health survey of general adult population. The analysis was further stratified by type of physical activity according to intensity.

Materials and Methods

Population

The Nanjing Community Cardiovascular Risk Survey was carried out, using random cluster sampling, between 2011and 2013 among the residents of 6 communities in Nanjing, Jiangsu Province, China (population 0.7 million-1.3 million). In each community, one street district or township was randomly selected. All households (n=6,445) in the selected street or town were included with only one participant aged ≥ 20 years selected from each household, without replacement. Overall, 5,824 residents completed the survey and examination (with a response rate of 90%). Questionnaires were completed, wherever possible, through face-to-face interviews by trained research staff. Questions included age, sex, and physical activities. Body measurements including body height and weight were taken three times using a standardized methodology and the mean of the two closest recordings was used. Body mass index (BMI) was calculated based on the obtained body height and weight using kg/m^2. Fasting blood specimens were processed at the examination centre. Creatinine levels were measured by Olympus AU600 automated analyser according to manufacturer's instructions (Olympus Optical, Tokyo, Japan).

Physical activity

Physical activity during a (usual) week (last week including weekdays and weekends) was collected by the long form International Physical Activity Questionnaire (IPAQ),[16] and was calculated as a sum of occupation, transportation, housework and recreational activity reported in metabolic equivalents of task (MET) × minutes per week. Physical activity with a period less than 10 minutes was not included as per the IPAQ guidelines.[16] MET is a physiological measure expressing the energy cost of physical activities and is defined as the ratio of metabolic rate (and therefore the rate of energy consumption) during a specific physical activity to a reference metabolic rate.[17] Physical activity in specific settings was summarised into groups based on the intensity of activity (Table 1). Stratified physical activity scores, including “walking”, “moderate” and “vigorous”, were obtained. In descriptive statistics, the total and intensity-stratified physical activity was categorised into “none” (0 MET × minutes per week), “not meeting” (1 - 599) or “meeting” (≥ 600) the current WHO physical activity guideline for people aged 18 – 64 years old.[18] 600 MET × minutes per week, equivalent to 150 minutes per week of moderate activity, was the lower limit for the recommended volume of physical activity.[18,19]

Measure of kidney function

Glomerular filtration rate is a measure of ability of kidney to clear plasma of nitrogenous wastes over a specific amount of time. At present, it was regarded as the best way to exam kidney function. The estimated glomerular filtration rate (eGFR, in mL/min/1.73 m^2) was calculated from serum creatinine using the Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) equation.[20]

Comorbidity

Type 2 diabetes and hypertension were the common risk factors of CKD. Plasma glucose was measured by the Olympus automated analyser. Type 2 diabetes was defined using the WHO criteria or by self-reported if previously diagnosed.[21] The blood pressure was taken three times using a standardized methodology and the mean of the two closest recordings was used.[22] Hypertension was recorded based on the WHO criteria or by self-reported if previously diagnosed.[23]

Statistical analysis

The demographic, physical activity and kidney function characteristics of the participants at the survey were first described. Using continuous variable, robust linear regression modelling was applied to assess the effect of physical activity (total and stratified by different intensity, measured by MET × minutes per week) on kidney function (measured by eGFR in mL/min/1.73 m^2), with adjustment for age, sex BMI, type 2 diabetes and hypertension. Robust regression is designed to reduce the effect by possible violation of assumption in linear regression models. Furthermore, to investigate the association of walking as a usual activity (walking MET × minutes per week > 0 vs. 0) with healthy kidney function (eGFR ≥ 90 vs. < 90), relevant measurements were grouped into binary variables. Logistic regression modelling then was used to analyse the effect of association, reported by odds ratio.

A sensitivity analysis which excluded participants whose eGFR < 60 was carried out. All statistical analysis was performed using STATA 12.

Approval and consent

This study was approved by the Institutional Review Board of Jiangsu Province Hospital on Integration of Chinese and Western Medicine (11–006). Signed, informed consent was obtained from all participants in the survey.

Results:

A total of 5,824 participants were included, with an average age of 52 years. 56% were females. Average body weight, height and BMI were 63 kg, 1.6 m and 24 kg/m^2, respectively (Table 2). The average eGFR among the participants was 76 mL/min/1.73 m^2, with 19% $\geq$ 90, 67% between 60 and 89, and 14% < 60 (Table 2). In average, the total physical activity during a week was 3,644 MET × minutes per week in the survey population (Table 2). Moderate activity contributed 64% of the total physical activity, followed by walking (23%) and vigorous activity (13%). 80% of the survey population reached the lower limit of the WHO's weekly recommendation on total physical activity (Table 3).

The total physical activity was weakly associated with eGFR ($p = 0.039$; see Table 4 model 1). However, in stratified analysis, only walking-related activity was associated with eGFR ($p < 0.0001$; see Table 4 model 2). In a linear regression model containing walking, moderate and vigorous activities together as independent variables and eGFR as dependent variable, the association of walking-related activity and eGFR remained ($p < 0.0001$, see Table 5). Logistic regression analysis showed that walking was associated with healthy kidney function with an OR of 2.23 (95% CI 1.91, 2.60), after adjustment for age, sex, BMI, type 2 diabetes and hypertension (Table 6).

Sensitivity analysis only showed similar results (data not shown).

Discussion:

In this large population survey, weekly physical activity (quantified by MET × minutes per week) of residents from urban communities in China was described. The kidney function in such participants estimated by eGFR was also determined. Only about 1 in 5 of the survey population had an eGFR $\geq$ 90 mL/min/1.73 m^2 considered as healthy kidney function, whereas there was 14% who showed clear evidence of reduced function in kidney (eGFR < 60). Benefit to the random sampling of survey and the high response rate, this estimate of kidney function may be representative to the urban residents in Nanjing (a large modern city in east China) if not to all the city populations across the country. Our data reflects the potential burden of kidney disease in China, and it should be raised as a public concern.

There is a disagreement in the literature as to whether higher physical activity is associated with better kidney function. In patients with CKD, higher physical activity level was associated with slower rate of eGFR loss,[24] whereas physical inactivity was associated with increased mortality.[14] However, the picture is not clear in the population without established kidney disease. In a study using the National Health and Nutrition Examination Survey data, it was shown that increased total and light physical activities were associated with improved kidney function (measured by eGFR), while moderate-vigorous physical activity was not significantly associated after adjustment for other confounding factors.[13] It is in line with our results showing that the increased total physical activity overall was associated with improved kidney function, but the actual positive effect was from walking-related activity. For the moderate and vigorous-related activity, although not significant the effect showed negative direction i.e. higher moderate/vigorous activity was related to reduced kidney function. In contrast, a recent longitudinal study demonstrated there was no association of physical activity with kidney function in participants aged 26 to 65 years from the Doetinchem Cohort study.[15] It has a better study design as it investigated the relationship between 5-year changes in physical activity and eGFR using time-lagged generalized estimating equation analysis. However, the study only reported the total activity while did not analyse the effects of subsets of physical activity according to intensity. In our study, the association of total physical activity with kidney function was only weak. Several studies showed that sedentary behaviour was associated with reduced renal function in different types of population.[13,25,26] However, we didn't investigate this relationship in the current study.

This study was firstly limited by its cross-sectional design, so no formal attempt with regard to causality would be discussed. However, our observation that higher moderate/vigorous physical activity was related to reduced kidney function (insignificant finding) implied the association of more walking with improved kidney function may be not due to the assumption that people with reduced kidney function tended to walk less. A sensitivity analysis which excluded participants with obviously reduced kidney function generated the same results. Secondly, data from questionnaire (self-reported records) can be biased due to many reasons such as response bias. However, thanks to the high response rate, such systematic error was not likely to be large. Although the study population was carefully selected using random cluster sampling and the survey tool was validated, the generalizability of study results has yet to be supported.

Walking is the most common aerobic activity, and it has been associated with reduced risk of many diseases such as heart disease, type 2 diabetes and asthma. However, it is one of many light physical activities, and the survey did not investigate other light activities. Aerobic activity, rather than anaerobic activity, may be associated with better kidney function and may explain the mechanism behind the current findings. Other limitations included that the data distribution of primary independent variable (i.e. physical activity in MET × minutes per week) was not optimal. To address this, we used robust regression modelling to reduce the effect by possible violation of assumption in linear regression models and used logistic regression modelling to estimate the relationship between walking as a usual activity and healthy kidney function.

In consolation, our study for the first time has shown that walking, but not other physical activity at a higher intensity, is associated with improved kidney function. Regular walking can be promoted and performed easily, a low cost strategy in maintaining kidney health as well as other benefits.

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Table 1 IPAQ questions on physical activity grouped by activity intensity

IPAQ items	By intensity
For heavy physical activity at work	Vigorous
For moderate physical activity at work	Moderate
For walking as part of your work	Walking
For bicycle to go from place to place	Moderate
For walking to go from place to place	Walking
For heavy physical activity in the garden or yard	Vigorous
For moderate physical activity in the garden or yard	Moderate
For moderate physical activity inside your home	Moderate
For walking during your leisure time	Walking
For heavy physical activity in your leisure time	Vigorous
For moderate physical activity in your leisure time	Moderate

IPAQ, International Physical Activity Questionnaire.

Table 2 Participant characteristics on demographics, physical activity, comorbid condition and renal function

Characteristics	Participants (n = 5,824)
	Mean (SD) or n (%)
Demographics	
Age, year	51.7 (9.9)
Male, %	2,546 (43.7)
Weight, kg*	62.8 (12.2)
Height, cm*	160.2 (7.8)
BMI, kg/m^2*	24.4 (4.1)
Comorbidity	
Type 2 diabetes, %	472 (8.1)
Hypertension, %	2,259 (38.8)
Physical activity (during a normal week)	
Total MET × minutes per week	3,644 (4,934)
MET × minutes per week by activity intensity	
Walking	833 (1,554)
Moderate	2,324 (3,266)
Vigorous	488 (2,771)
Renal function	
eGFR (in mL/min/1.73 m^2)*	76.3 (16.9)
eGFR group*	
≥ 90	1,117 (19.2)
60 - 89	3,886 (66.8)
30 - 59	812 (14.0)
< 30	6 (0.1)

BMI, the body mass index; MET, the metabolic equivalent of task; eGFR, the estimated glomerular filtration rate; *Weight on 5,762 subjects; Height on 5,741 subjects; BMI on 5,739 subjects; eGFR on 5,821 subjects.

Table 3 Physical activity in the study population, measured by MET × minutes per week and stratified by activity intensity

Activity group (MET × minutes per week)	Walking, n (%)	Moderate, n (%)	Vigorous, n (%)	Total, n (%)
0	2,183 (37.5)	714 (12.3)	5,274 (90.6)	370 (6.4)
1 – 599	1,655 (28.4)	1,234 (21.2)	178 (3.1)	772 (13.3)
≥ 600	1,986 (34.1)	3,876 (66.6)	372 (6.4)	4,682 (80.4)

MET, the metabolic equivalent of task.

Table 4 The relationship of total and intensity-stratified physical activity with eGFR in separate models

Independent variable	Regression coefficients (95% CI)	p value
Model 1, total activity	0.00008 (0.000004, 0.00015)	0.039
Model 2, walking-related activity	0.0012 (0.0010, 0.0015)	< 0.0001
Model 3, moderate-related activity	0.00002 (-0.00009, 0.00013)	0.72
Model 4, vigorous-related activity	-0.00008 (-0.00022, 0.00005)	0.22

eGFR, the estimated glomerular filtration rate; CI, confidence interval; Robust regression analysis: Dependent variable, eGFR; Adjusted for age, gender, BMI, type 2 diabetes and hypertension; Participants in the model n = 5,736.

Table 5 The relationship between intensity-stratified physical activity and eGFR within one model

Independent variable	Regression coefficients (95% CI)	p value
Walking-related activity	0.0013 (0.0010, 0.0015)	< 0.0001
Moderate-related activity	-0.00007 (-0.00018, 0.00005)	0.24
Vigorous-related activity	-0.00012 (-0.00025, 0.00002)	0.09
Age	-0.60 (-0.64, -0.56)	< 0.0001
Male	6.32 (5.57, 7.08)	< 0.0001
BMI	-0.31 (-0.41, -0.22)	< 0.0001
Type 2 diabetes	-3.05 (-1.67, -4.43)	< 0.0001
Hypertension	-0.54 (-1.37, 0.28)	0.20

eGFR, the estimated glomerular filtration rate; CI, confidence interval; Robust regression analysis: Dependent variable, eGFR; Participants in the model n = 5,736.

Table 6 The association of walking with healthy kidney function

	Healthy kidney function
Independent variable	OR (95% CI)
Walking	2.23 (1.91, 2.60)
Age	0.96 (0.95, 0.96)
Male	1.48 (1.29, 1.70)
BMI	0.96 (0.94, 0.98)
Type 2 diabetes	0.60 (0.47, 0.67)
Hypertension	0.87 (0.74, 1.02)

eGFR, the estimated glomerular filtration rate; OR, odds ratio; CI, confidence interval; Logistic regression analysis: Dependent variable, healthy kidney function (eGFR ≥ 90 mL/min/1.73 m^2 vs. < 90); Participants in the model n = 5,736.