Original Article

High Physical Activity is Associated with an Improved Lipid Profile and Resting Heart Rate among Healthy Middle-aged Chinese People

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Abstract

Objective To investigate the effects of physical activity (PA) on dyslipidemia and elevated resting heart rate (RHR) in a large-scale cross-sectional study in China.

Methods We recruited community-based individuals who were 40-60 years old using a cluster sampling method. The PA levels of the participants were classified as low, moderate, or high, using the International Physical Activity Questionnaire. Dyslipidemia was defined as the detection of abnormalities in lipid indicators, and 4 lipid parameters were evaluated using fasting blood samples. Multivariate logistic regression analyses were used to evaluate the associations of PA with dyslipidemia and RHR.

Results A total of 10,321 participants (38.88% men) were included in this study. The percentages of individuals with high, moderate, and low PA levels were 46.5%, 43.9%, and 9.6%, respectively. In both men and women, high PA provided odds ratios of 0.88 [95% confidence interval (CI): 0.83, 0.94] for dyslipidemia and 0.82 (95% CI: 0.73, 0.92) for elevated RHR, compared to participants with low PA.

Conclusion Our data suggested that substantial health benefits (related to dyslipidemia and elevated RHR) occurred at higher intensity PA, with greater energy consumption, in middle-aged Chinese people, and particularly in men.

Key words: Physical activity; Lipid profile; Dyslipidemia; Heart rate; Unconditional logistic regression

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INTRODUCTION

Elevated levels of lipids in the blood can lead to significant chronic health problems. For example, increased amounts of fat and cholesterol in the blood, which is known as dyslipidemia, are associated with an increased risk of coronary heart disease[1-2] and stroke[3-4]. In addition, the 2002 World Health Report[5] estimated that 7.6% of the disease burden in developed countries, and approximately 2% of the burden in developing countries, was caused by elevated blood cholesterol levels. Furthermore, 56% of ischemic heart disease cases and 32% of ischemic stroke cases in World

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Health Organization (WHO) regions are due to high blood cholesterol levels. Unfortunately, dyslipidemia may be caused by an unhealthy diet and lifestyle (80%) or by hereditary familial disorders (20%)[6]. Elevated serum levels of lipids also have a multifactorial etiology that is determined by a large number of environmental and genetic factors. In addition, diet, physical inactivity, and socioeconomic and cultural factors are associated with both obesity and dyslipidemia[7]. Furthermore, variations in the genes of enzymes, receptors, and apolipoproteins are partially involved in regulating serum levels of low-density lipoprotein cholesterol (LDL-C) and total cholesterol[8].

An elevation in resting heart rate (RHR) is also associated with cardiovascular disease. Epidemiological evidence suggests that an elevated RHR is associated with increased cardiovascular morbidity and mortality in the general population, independent of the conventional risk factors[9-10]. Hall and Palmer[11] have also determined that a 2% reduction in death was associated with each 1 beat/min reduction in heart rate. In addition, elevated RHR has been associated with a poorer prognosis within subgroups of patients with cardiovascular disease[12].

Physical activity (PA) is of major importance in regulating health, as it is strongly associated with obesity and a number of diseases, including metabolic disorders[13]. Several previous intervention trials had been performed to explore the associations between PA and serum lipid levels[14-16], and most of these trials have reported that high levels of PA were associated with low serum lipid levels. However, due to the use of various exercise interventions and the different characteristics of the studies' populations, the influence of PA on lipid profiles remains uncertain[6,14-15]. In addition, the type and intensity of PA that produces the most beneficial effects also remain unclear, and the effects of PA on serum lipid levels are inconsistent in different studies[15-16]. Moreover, the lipid profiles of men and women exhibit different responses to PA[17-18].

Similar to the association between PA and lipid profiles, previous studies have demonstrate that subjects with a higher PA had lower RHRs, compared to physically inactive subjects[19-20]. However, Black et al.[21] did not observe this trend in young female adults, after adjusting for covariates. In addition, to our best knowledge, PAs that were performed at work and in the home have rarely been considered together in the previous studies. Therefore, the goal of this study was to evaluate the influences of total PA on dyslipidemia and RHR, according to sex, in a middle-aged population of Chinese people.

METHODS

Sampling

We used a cluster sampling method to recruit subjects from urban and rural areas in Hebei, China between 2009 and 2011. First, due to feasibility considerations, 5 communities (urban) and 5 villages (rural) in three cities of Hebei province were initially screened. Next, after evaluating their representative nature, 4 communities and 3 villages were selected for inclusion in the study. Finally, 15,851 residents who were 40-60 years old and had lived in these communities and villages for >5 years were included in the study. The Ethics Committee of Hebei United University (Tangshan, China) approved the study's design, and all subjects gave their informed consent to participate.

Among the included individuals, 13,648 subjects completed the questionnaire and laboratory tests, providing a final response rate of 86.1%. Participants were excluded if they had a history of hypertension, diabetes, cardiovascular disease, or stroke (2973 subjects); regularly took anti-hypertensive, lipid-lowering, or hypoglycemic agents within 1 month (60 subjects); or had missing data regarding physical activity, lipid levels, and the main demographic variables (including age and sex) (294 subjects). Based on these exclusions, 10,321 subjects (4013 men and 6308 women) were included in the statistical analysis.

Data Collection

Data were collected in examination centers at the local health stations or at community clinics in the participants' residential areas. The quality of the data that were collected was maintained by using standardized protocols and centralized training. At each center, all data were entered into an electronic customized database that was programmed with the appropriate ranges, and were then re-checked for consistency using quality control measures.

Questionnaire Survey

Structured pre-test questionnaires were administered via face-to-face interviews. The first part of the survey was designed to collect basic information from the respondents, including age, sex, marital status, education, tobacco use, alcohol use, depression, stress from work/home, and frequency of food consumption. The second part of the survey was designed to collect information regarding the respondents' health via self-reporting, and evaluated chronic diseases, current illnesses, past medical history, and treatment history for related illnesses, such as hypertension, diabetes, cardiovascular disease, and stroke. A family history of any chronic disease was also evaluated. The third part of the survey used the long form International Physical Activity Questionnaire (IPAQ)[22] to assess the respondents' PA. In this part of the survey, we evaluated a comprehensive set of 4 domains: domestic and gardening activities, transportation-related activities, leisure-time PA, and work-related PA. Participants were asked on the questionnaire to estimate the average time per week that they spent on the different levels of activities in the 4 domains. A metabolic equivalent task (MET) score was assigned to each of these activities, based on their energy costs, and the sum of all the activities was used to estimate the total energy that was expended on PA.

Physical Examination and Laboratory Tests

Standard physical examinations of height and weight were performed for each subject, immediately after they completed the questionnaires. Body weight and height were measured twice during the examination, and the average values were used to calculate the subject's body mass index (BMI), which was defined as weight (kg) divided by height squared (m^2). In addition, we performed three RHR and blood pressure measurements, separated by 5 min of rest, using a digital automatic blood pressure monitor (OMRON, HEM-7200) and with the subject in the seated position. The last two results were recorded, and the average of the two results was used for the analyses. Participants were advised to avoid smoking, alcohol, caffeinated beverages, and exercise for at least 30 min before their RHR and blood pressure measurements.

Blood samples were collected in the early morning, with the subject having fasted for at least 8 h. These samples were immediately stored in insulated ice-filled containers, and were centrifuged, aliquoted, and stored at -70 °C in freezers within 2 h of the collection. Fasting plasma glucose was measured using a modified hexokinase enzymatic method. Concentrations of total cholesterol (TC) and triglycerides (TG) were determined enzymatically using the GPO-PAP and COD-CE-PAP methods, respectively. High-density lipoprotein cholesterol (HDL-C) levels and LDL-C levels were measured via the direct method. All reagents were obtained from Sichuan Maker Biotechnology Co. Ltd., Chengdu, China.

Diagnostic Criteria

The categorical indicators of PA that were extracted from the IPAQ forms were low, moderate, and high levels of PA. Individuals who met at least one of the following criteria were defined as having a moderate level of PA: ≥3 d of vigorous activity for at least 20 min per day; ≥5 d of moderate-intensity activity and/or walking for at least 30 min per day; or ≥5 d with any combination of walking, moderate-intensity activity, or vigorous activity that achieved a minimum total PA of ≥600 MET-min per week. Individuals who met one of the following two criteria were classified as having a high level of PA: vigorous activity for ≥3 d and ≥1500 MET-min per week, or 7 or more days with any combination of walking, moderate-intensity activity, or vigorous activity that achieved a minimum total PA of ≥3000 MET-min per week. Individuals who did not meet the criteria for moderate or high PA were classified as having low PA.

The categorical indicators of lipid profiles were defined according to the criteria that are outlined in the report of Chinese guidelines on the prevention and treatment of dyslipidemia in adults[23], which defines dyslipidemia as: high TC (≥6.22 mmol/L), high TG (≥2.26 mmol/L), high LDL-C (≥4.14 mmol/L), or low HDL-C (<1.04 mmol/L). Hjalmarson et al.[24] have reported that a heart rate of >90 beats/min was an independent predictor of mortality at one year after myocardial infarction, and Spodick et al.[25] have suggested that a normal heart rate range should be defined as 50-90 beats/min. Therefore, 90 beats/min was set as the cut-off point for defining an elevated RHR in this study.

Definition of Variables

Marital status was initially classified into 6 categories: never married, currently married, common law/living with partner, widowed, separated, or divorced. However, after considering the number of subjects in each category, we converted marital status into 2 categories. In this classification, never married, widowed, divorced, and separated were combined as 'single', while currently married or living with a partner/common-law spouse were combined as 'not single'. The highest level of education was also initially classified into 5 categories: illiterate, primary school, junior high school, high school/secondary specialized school/secondary technical school, or junior college/university. However, after considering the number of subjects in each of these categories, the 5 categories were also converted into 3 categories: primary (illiterate and primary school), secondary (junior high school and high school/secondary specialized school/secondary technical school), and senior (junior college/university). Tobacco and alcohol use was classified into 3 categories: never, formerly, and current. Stress was defined as feeling irritable or anxious, or having sleeping difficulties within the last year as a result of conditions at work or at home, and was classified into 4 categories: never experienced stress, had some periods of stress, had several periods of stress, or experienced permanent stress[26]. Vegetable and fruit consumption was assessed using the amounts of vegetables or fruits that were consumed in the past year (calculated as: quantity per time × consumption time). Fatty food consumption was calculated using the amounts of meat, egg, milk, and fish that were consumed in the past year (quantity per time × consumption time). These data were provided via self-reports, and all analyses were based on these categories.

Statistical Analysis

The baseline characteristics for continuous variables (age, BMI, TC, TG, HDL-C, LDL-C, RHR, fatty foods intake, and vegetables and fruits intake) were described as mean±standard deviation or median (25% and 75% percentiles). The continuous variables were compared using Student's *t*-test or the appropriate nonparametric tests, depending on the data's normality. The frequencies for categorical variables (sex, tobacco use, alcohol use, education, marital status, and stress) were compared using the chi-square test. *P*-values for trend were derived from the univariate linear regression analysis or the chisquare test results, depending on the variable type.

Multivariate logistic regression models were used to evaluate the association between PA (the independent variable) and each type of dyslipidemia or RHR (the dependent variables), after adjusting for the confounding factors (age, sex, BMI, fatty foods intake, vegetables and fruits intake, tobacco use, alcohol use, education, marital status, and stress). Because numerous subjects had more than two abnormalities, four types of dyslipidemia were defined, according to the number of involved components (one abnormality, two abnormalities, three abnormalities, and all abnormalities), to describe the association between PA and the different types of dyslipidemia. The strength and direction of the associations were evaluated using odds ratios (OR) and the corresponding 95% confidence intervals (CI). We also created dummy variables for the multi-categorical variables (tobacco use, alcohol use, and education), and used them in our models. Log transformations were performed for non-normally distributed independent variables (fatty foods intake and vegetables and fruits intake) before inclusion in the multivariate analysis. *P*-values of <0.05 were considered statistically significant, and all statistical tests were 2-sided. All statistical analyses were performed using SAS software (version 9.13, SAS Institute Inc., North Carolina, USA).

RESULTS

A total of 10,321 participants were included in this study. The mean age of the participants was 49.75±5.62 years, and 38.88% of the participants were men. The percentages of individuals with high, moderate, and low PA levels were 46.5%, 43.9%, and 9.6% respectively. The mean levels of TC, TG, HDL-C, LDL-C, and RHR for the total population were 4.52 mmol/L, 1.21 mmol/L, 1.35 mmol/L, 2.53 mmol/L, and 73.78 beats/min, respectively. A decreasing trend was observed in the proportion of male, RHR, fatty food intake and stress with increasing PA levels, by trend test. However, an increasing trend was observed in HDL-C levels and vegetable/fruit intake with increasing PA levels (Table 1).

Table 2 shows the frequencies of dyslipidemia and elevated RHR for the different PA levels. In the total and male populations, elevated TG and decreased HDL-C levels were positively associated with PA levels. In contrast, elevated TC and LDL-C levels were negatively associated with PA levels in the total and female populations (*P* for trend <0.05 for all comparisons). No association between elevated RHR and PA levels was observed in men or in women.

After accounting for the potentially confounding effects of age, BMI, fatty food intake, vegetable and

Table 1. Characteristics of the Participants

Variables	Physical Activity		
	Low (995)	Moderate (4531)	High (4795)
Age (year)	49.49±5.79	49.69±5.65	49.86±5.56
Sex: male, *n* (%)[#]	551 (55.38)	1611 (35.56)	1851 (38.60)
BMI (kg/m^2)	24.49±3.76	24.42±3.84	24.23±3.91
TC (mmol/L)	4.50±0.79	4.52±0.84	4.53±0.85
TG (mmol/L)[*]	1.25 (0.90, 1.80)	1.24 (0.89, 1.75)	1.17 (0.85, 1.68)
HDL-C (mmol/L)[#]	1.32±0.31	1.34±0.30	1.37±0.31
LDL-C (mmol/L)	2.50±0.67	2.53±0.68	2.54±0.68
RHR (beats/min)[#]	74.22±10.11	74.24±10.27	73.25±10.24
Fatty foods intake (g/d)[*,#]	133.42 (71.95, 199.32)	131.84 (73.73, 212.74)	131.51 (69.86, 208.49)
Vegetables and fruits intake (g/d)[*,#]	429.25 (301.64, 617.40)	469.86 (300.00, 639.45)	530.96 (339.73, 680.55)
Tobacco use, *n* (%)			
Never	556 (57.35)	3230 (72.75)	3311 (69.93)
Formerly	46 (4.66)	129 (2.91)	148 (3.13)
Current	375 (37.99)	1081 (24.35)	1276 (26.95)
Alcohol use, *n* (%)			
Never	17 (1.75)	79 (1.79)	83 (1.77)
Formerly	723 (74.54)	3331 (75.31)	3491 (74.55)
Current	230 (23.71)	1013 (22.90)	1109 (23.68)
Education, *n* (%)			
Primary	234 (23.59)	1176 (26.02)	1192 (24.92)
Secondary	690 (69.56)	3087 (68.31)	3339 (69.81)
Senior	68 (6.85)	256 (5.66)	252 (5.27)
Marital status, *n* (%)			
Single	42 (4.22)	174 (3.84)	214 (4.46)
Stress, *n* (%)[*,#]			
Yes	500 (50.25)	1788 (39.46)	1907 (39.77)

Note. [*]Reported as median (Q1, Q3); [#]*P*-value for trend of PA levels <0.05. BMI: body mass index; TC: total cholesterol; TG: triglycerides; HDL-C: high-density lipoprotein cholesterol; LDL-C: low-density lipoprotein cholesterol; RHR: resting heart rate.

Table 2. Distributions of the Different Types of Dyslipidemia and Elevated Heart Rate According to Physical Activity Levels and Sex

Variables	Physical Activity			*P*-value for Trend
	Low	Moderate	High	
Total, *n* (%)				
TC≥6.22 mmol/L	19 (1.91)	148 (3.27)	174 (3.63)	0.013
TG≥2.26 mmol/L	162 (16.28)	597 (13.18)	575 (11.99)	<0.001
HDL-C<1.04 mmol/L	174 (17.49)	714 (15.76)	645 (13.45)	<0.001
LDL-C≥4.14 mmol/L	7 (0.70)	68 (1.50)	88 (1.84)	0.011
RHR>90 beats/min	72 (7.24)	322 (7.11)	288 (6.01)	0.033
Male, *n* (%)				
TC≥6.22 mmol/L	11 (2.00)	38 (2.36)	46 (2.49)	0.532
TG≥2.26 mmol/L	102 (18.51)	277 (17.19)	246 (13.29)	<0.001
HDL-C<1.04 mmol/L	117 (21.23)	321 (19.93)	306 (16.53)	0.003
LDL-C≥4.14 mmol/L	4 (0.73)	17 (1.06)	23 (1.24)	0.306
RHR>90 beats/min	34 (6.17)	98 (6.08)	90 (4.86)	0.118
Female, *n* (%)				
TC≥6.22 mmol/L	8 (1.80)	110 (3.77)	128 (4.35)	0.018
TG≥2.26 mmol/L	60 (13.51)	320 (10.96)	329 (11.18)	0.438
HDL-C<1.04 mmol/L	57 (12.84)	393 (13.46)	339 (11.51)	0.058
LDL-C≥4.14 mmol/L	3 (0.68)	51 (1.75)	65 (2.21)	0.026
RHR>90 beats/min	38 (8.56)	224 (7.67)	198 (6.73)	0.080

Note. The *P*-value for trend was derived using the chi-square test results. TC: total cholesterol; TG: triglycerides; HDL-C: high-density lipoprotein cholesterol; LDL-C: low-density lipoprotein cholesterol; RHR: resting heart rate.

fruit intake, tobacco use, alcohol use, education, marital status, and stress, the multivariate logistic regression analysis (Table 3) revealed that high PA was associated with elevated TG and RHR, and with decreased HDL-C, in the total and male populations (P<0.05 for all comparisons). However, high PA was only associated with elevated RHR in the female population. In addition, moderate PA did not affect the different types of dyslipidemia or elevated RHR in men or women.

Table 4 shows the associations between PA and the extent of dyslipidemia according sex. After adjusting for the risk factors, vigorous PA was associated with all abnormalities in the total population

Table 3. Risk for the Different Types of Dyslipidemia and Resting Heart Rate According to Physical Activity Levels and Sex

Variables	Low			Moderate			High		
	OR	95% CI	P	OR	95% CI	P	OR	95% CI	P
Total*									
TC≥6.22 mmol/L	1	-	-	1.00	0.72, 1.40	0.991	0.80	0.57, 1.11	0.185
TG≥2.26 mmol/L	1	-	-	0.95	0.83, 1.09	0.450	0.79	0.66, 0.95	0.014
HDL-C<1.04 mmol/L	1	-	-	0.98	0.66, 1.49	0.950	0.86	0.79, 0.95	0.002
LDL-C≥4.14 mmol/L	1	-	-	1.45	0.89, 2.37	0.144	1.89	1.09, 3.29	0.024
RHR>90 beats/min	1	-	-	0.78	0.62, 1.01	0.051	0.82	0.73, 0.92	0.001
Male									
TC≥6.22 mmol/L	1	-	-	1.17	0.58, 2.62	0.362	1.13	0.71, 2.54	0.205
TG≥2.26 mmol/L	1	-	-	0.99	0.66, 1.49	0.957	0.76	0.62, 0.94	0.009
HDL-C<1.04 mmol/L	1	-	-	0.93	0.82, 1.05	0.253	0.64	0.45, 0.85	0.000
LDL-C≥4.14 mmol/L	1	-	-	2.20	0.88, 5.48	0.883	1.73	0.95, 3.19	0.075
RHR>90 beats/min	1	-	-	0.84	0.60, 1.19	0.330	0.76	0.63, 0.93	0.008
Female									
TC≥6.22 mmol/L	1	-	-	1.36	0.90, 2.04	0.141	2.00	0.95, 3.95	0.081
TG≥2.26 mmol/L	1	-	-	0.95	0.83, 1.09	0.450	0.78	0.42, 1.56	0.189
HDL-C<1.04 mmol/L	1	-	-	0.93	0.53, 1.66	0.816	0.81	0.56, 1.18	0.623
LDL-C≥4.14 mmol/L	1	-	-	1.29	0.26, 5.28	0.809	2.37	0.71, 7.62	0.173
RHR>90 beats/min	1	-	-	0.47	0.36, 1.69	0.173	0.86	0.80, 0.92	0.000

Note. *Also adjusted for sex. All odds ratios were calculated relative to a low level of physical activity, and were adjusted for age, body mass index, fatty foods intake, vegetables and fruits intake, tobacco use, alcohol use, education, marital status, and stress. OR: odds ratio; CI: confidence interval; TC: total cholesterol; TG: triglycerides; HDL-C: high-density lipoprotein cholesterol; LDL-C: low-density lipoprotein cholesterol; RHR: resting heart rate.

Table 4. Risk for the Different Types of Dyslipidemia According to Physical Activity Levels and Sex

Variables	n	Low			Moderate			High		
		OR	95% CI	P	OR	95% CI	P	OR	95% CI	P
Total*										
All abnormalities	2813	1	-	-	0.96	0.83, 1.25	0.264	0.88	0.83, 0.94	0.000
One abnormality	2275	1	-	-	0.93	0.74, 1.38	0.617	0.83	0.67, 1.01	0.062
Two abnormalities	518	1	-	-	0.88	0.61, 1.24	0.392	0.81	0.64, 1.07	0.135
Three abnormalities	20	1	-	-	1.09	0.11, 9.34	0.852	1.48	0.17, 10.67	0.521
Male										
All abnormalities	1267	1	-	-	0.93	0.71, 1.53	0.485	0.71	0.54, 0.93	0.014
One abnormality	1030	1	-	-	0.81	0.62, 1.15	0.216	0.88	0.80, 0.97	0.012
Two abnormalities	233	1	-	-	1.13	0.78, 1.96	0.702	0.77	0.63, 0.93	0.008
Three abnormalities	4	1	-	-	-	-	-	-	-	-
Female										
All abnormalities	1546	1	-	-	1.02	0.79, 1.28	0.853	1.02	0.77, 1.31	0.847
One abnormality	1245	1	-	-	1.01	0.79, 1.29	0.930	1.04	0.80, 1.35	0.912
Two abnormalities	285	1	-	-	0.93	0.56, 1.54	0.771	0.95	0.54, 1.68	0.855
Three abnormalities	16	1	-	-	0.77	0.11, 7.01	0.837	1.02	0.11, 9.36	0.418

Note. *also adjusted for sex. All odds ratios were calculated relative to a low level of physical activity, and were adjusted for age, body mass index, fatty foods intake, vegetables and fruits intake, tobacco use, alcohol use, education, marital status, and stress. No results were calculated for men with three abnormalities, due to the limited sample size. OR: odds ratio; CI: confidence interval.

(OR: 0.88, 95% CI: 0.83, 0.94). However, this association was not observed for moderate PA. Compared to men with low levels of PA, men with vigorous PA exhibited significant associations with one abnormality, two abnormalities, and all abnormalities (all, $P<0.05$). In contrast, the association between vigorous PA and dyslipidemia was not observed in women (all, $P>0.05$). Furthermore, no association between moderate PA and dyslipidemia was observed in men or in women (both, $P>0.05$).

DISCUSSION

The results of our study demonstrate that, compared to low PA and after adjusting for potential confounders, high PA was associated with dyslipidemia in our middle-aged Chinese subjects, especially in men. However, this association was not observed for moderate PA. Several large studies have explored the relationship between PA and lipid profiles, and have reported similar findings. For example, the ATTICA study surveyed health and nutrition in Greece, and reported that various levels of PA affected cardiovascular disease risk factors in 3042 subjects[27]. In that study, the PA data were also collected using a translated version of the IPAQ, and participants were classified as inactive, sufficiently active, highly active, or having performed a combination of aerobic and resistance exercise (HAC). After adjusting for potentially confounding factors (age, BMI, educational status, dietary habits, smoking habits, hypertension, and diabetes mellitus), the men and women in the HAC group had TC levels that were 5% and 6.3% lower than those of the inactive controls, respectively. Men in the HAC group also had LDL-C levels that were 10% lower than those in both sufficiently active and inactive men. Women in the HAC group had LDL-C levels that were 11.9% and 13.5% lower than those of inactive and sufficiently active women, respectively. Therefore, the results of the ATTICA study suggest that high levels of activity (via a combination of aerobic and resistance exercise) may provide a more favorable effect on lipid levels, compared to inactivity or sufficient activity. In America, two cross-sectional studies explored the association between total running distance and lipid levels or other coronary heart disease risk factors among 1837 female[28] and 8283 male[29] runners, using physician-provided medical data. These studies reported that significantly lower TC levels, and greater HDL-C levels, were found in the groups of female and male runners with the greatest running distance, compared to the lowest distance groups. In addition, a significant inverse dose-response relationship was observed between running distance and both LDL-C and TG levels in men. Furthermore, the randomized and controlled STRIRIDE study[30] evaluated the effects of exercise amount and intensity on the risk factors for cardiovascular disease among overweight and obese subjects. The results indicated that the highest level of weekly exercise had widespread beneficial effects on the subjects' lipoprotein profiles. In that study, 84 participants were randomized into a control group (a 6-month sedentary period) and three 8-month exercise groups (low volume/ moderate intensity, low volume/vigorous intensity, high volume/vigorous intensity). According to the intention-to-treat analysis, the 22 overweight participants in the high volume/vigorous intensity group experienced an approximately 10% increase in their HDL-C levels, and a 20% decrease in their TG levels. In addition, the ranked effects of the exercise amount and intensity revealed that high volume/high intensity exercise had a greater effect on lipid profiles, compared to that observed for low volume/high intensity exercise. These findings demonstrate a clear relationship between the amount of exercise and lipid parameters, whereby higher intensity exercise has greater effects on the lipid parameters.

Our results demonstrated that the lipid profiles of middle-aged men and women exhibit different responses to PA. Similarly, Lee[17] reported that no significant positive changes were observed in the lipid profiles of obese middle-aged women after 24 weeks of combined folk dance and resistance training. In addition, LeMura et al.[18] recruited 12 young women to participate in 16 weeks of resistance training, and reported no significant changes in their lipid profiles, compared to those of the non-intervention group. Therefore, it appears that the causes of the different effects of PA in men and women are complex and variable. In this context, several studies have demonstrated that sex-related differences in lipid metabolism may be the result of a complex network of hormone actions in combination with other factors[31], which may explain the sex-related effects of PA. In addition, loss of ovarian function after menopause, and hyperandrogenemia in women with polycystic ovary syndrome, appears to cause an increase in plasma TG and LDL-C levels, and a decrease in HDL-C levels[32-33]. Therefore, until these sex-related differences in lipid metabolism are better understood, future studies regarding the relationship between PA and lipid profiles may benefit from investigating men and women separately.

The idea that physical training can decrease RHR is recognized by most researchers. In the Diabetes Prevention Program, an intensive lifestyle intervention (which included physical activity and a low fat diet) reduced heart rate, compared to the effects of metformin or placebo[34]. Similarly, our results indicate that high PA can counteract elevated RHR in both men and women. In the total study population, we found that the vigorous PA group had an RHR that was approximately 1 beats/min slower than that of the low and moderate PA groups. Furthermore, it has been reported that a 2% reduction in death was associated with each 1 beat/min reduction in heart rate[11]. Therefore, given the ubiquitous nature of both PA and dyslipidemia, even a minor decrease in RHR would have enormous public health consequences. However, we found that moderate PA was not associated to RHR in this study’s middle-aged Chinese population. Thus, further studies regarding the association between PA intensity and RHR are needed.

In our study, the number of subjects with low PA (995, 9.6%) was less than the number of subjects with moderate or high PA. This finding is similar to the results of the WHO’s World Health Survey[35], which reported inactivity rates of approximately 10% for China. Bauman et al.[36] have also reported that >30% of all physical activity is derived from walking, which suggests that countries with an infrastructure or culture that supports walking can achieve high levels of physical activity with lower levels of high-intensity activity in China. Although the long-form IPAQ's reliability and validity are acceptable among Chinese seniors[37], the usage of the IPAQ must be caution and requires additional investigation.

This study had several limitations. First, the study used a cross-sectional design, and cannot infer the causality of the relationships that we observed. Second, selection bias might have been introduced, as we restricted the participants to persons who were 40-60 years old, and the influence of PA on metabolic disease and dyslipidemia may vary according to age. Third, we only evaluated the consumption frequency for vegetable/fruit intake and specific fatty foods (meats, fishes, eggs, and milk), and did not evaluate the consumption of other relevant foods (such as nuts, edible oil, sweet drinks, and snacks). Fourth, some data (e.g., stress and personal medical history) were obtained via self-reporting by the subjects. However, our study also has several advantages, including the large sample size, a high level of quality control, standardized methods for data collection, and laboratory testing that was performed by trained research assistants.

CONCLUSIONS

Our data suggested that substantial health benefits (related to dyslipidemia and elevated RHR) occurred at higher intensity PA, with greater energy consumption, in middle-aged Chinese people, and particularly in men.

AUTHORS' CONTRIBUTIONS

Conceived and designed the experiments: HU Bo. Performed the field investigation: HU Bo, LIU Xiao Yu, ZHENG Yao, GUO Chun Yue, LI Yun, WU Shou Ling, FENG Fu Min, YUAN Ju Xiang. Performed quality control: FAN Hong Min, YIN Su Feng. Entered and processed the data: ZHENG Yao, GUO Chun Yue, LI Yun, WU Shou Ling, FENG Fu Min, YUAN Ju Xiang. Analyzed the data: FAN Hong Min, YIN Su Feng. Wrote the manuscript: HU Bo, LIU Xiao Yu.

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