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Physical activity, diet and cardiovascular disease risks in Chinese women

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Abstract

Objective: To investigate the relationship between different types and levels of physical activity and cardiovascular disease risk factors, including oxidative stress, blood lipids and insulin resistance, in a healthy female population in China.
Method: Healthy women ($n = 761$) aged 35 to 65 years participated in this study. The habitual physical activity was evaluated by self-administered questionnaire (MOSPA). The dietary intakes of nutrients were calculated from 3-day recall records. Anthropometric data of each subject were measured, fasting blood samples were taken, and erythrocytes and serum were prepared for the measurement of erythrocyte superoxide dismutase activity, serum malondialdehyde, total antioxidant capacity, insulin, glucose and lipids (total cholesterol, triglycerides, apolipoprotein AI (apo A) and apolipoprotein B (apo B)) concentrations.
Results: Low level of physical activity was related to a lower concentration of serum apo B, and higher energy expenditure from household physical activity had a reverse relationship with serum apo B and triglyceride levels. In the group with moderate occupational energy expenditure, the concentration of serum triglycerides was lower, but that of high-density lipoprotein was higher. Moderate energy expenditure (less than 1700 kcal day^{-1}) from leisure-time physical activity was positively related to total antioxidant capacity and insulin sensitivity. However, heavy occupational physical activity may be not beneficial for the cardiovascular system.
Conclusion: This study indicates that leisure-time, moderate occupational and household physical activity levels decreased risk factors for cardiovascular disease.

Keywords
Physical activity
coronary heart
disease Diet

Cardiovascular disease (CVD) is still one of the leading causes of death in Western societies. The incidence of coronary heart disease (CHD) – a major type of CVD – has increased dramatically in the Chinese population during the last decade as lifestyles and dietary patterns have changed, becoming more similar to Western ones[1]. A number of epidemiological and laboratory studies from Western societies have provided evidence that high intake of dietary fat, less physical activity, high levels of plasma cholesterol and triglycerides, obesity and smoking are classical risk factors for CHD[2–4]. Recent studies have revealed that, in addition to the classical risk factors for CHD, several new risk factors play important roles in the initiation and progression of CHD, such as elevated oxidative stress, oxidised low-density lipoprotein (LDL) and elevated plasma homocysteine concentration[5–7]. Among the classical and new risk factors, diet and physical activity are the most easily modifiable ones, having the characteristics of safety, practicability and good cost-efficiency in the prevention of CVD. Programmes in the USA and Finland to reduce dietary fat intake and to increase physical activity have greatly lowered (10–20%) the incidence of CHD in the last two decades[8,9].

In the past, most studies of the influence of physical activity on cardiovascular health have been related to leisure-time physical exercise, seldom to other types of habitual physical activity such as occupational and household physical activity[10–12]. Male populations or illness populations have often been investigated, but healthy women, especially Chinese women, have been studied much less. Whether or not habitual types of physical activity are equally beneficial for women and how they manifest in a female population have not been fully investigated.

Abundant evidence shows that diet is important among the CVD risk factors. China has been a country with a low incidence of atherosclerosis and CHD, and the traditional Chinese diet might be a good approach to reaching good cardiovascular health. The traditional Chinese diet was rich in carbohydrate (about 60% of energy intake), fruits and vegetables. During the last decade, the dietary regime has changed to contain more meat and animal fat and less

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fruits and vegetables. The consequence on cardiovascular health from this dietary change has been investigated widely in the Chinese population. However, it is necessary to compare separately the influence of dietary factors and physical activity as CVD risk factors.

The aim of the present study was investigate the relationship between different types and levels of physical activity and risk factors for CVD, including blood lipids, insulin resistance and antioxidant status, in healthy Chinese females taking diet into account.

Subjects and methods

Subjects

Female subjects ($n = 761$, 35 to 65 years of age) in 12 state-invested units including factories, enterprises, schools and government offices, who were judged healthy by medical history and routine clinical examination, were recruited for this study. Cluster sampling from all factories or enterprise units in the city of Jiangmen, Guangdong Province was employed. Not only currently employed female workers but also retired women were investigated. All subjects gave their informed consent to participate in this study. None of the subjects had any cardiovascular and other chronic diseases, and none was receiving medication or taking any nutritional supplements one month before the study. The study was approved by the Ethic Committee of Zhonshan University. Each subject completed a self-administrated questionnaire providing basic demographic information as well as menstrual and reproductive histories before initiation of the study period.

Anthropometric measurements (height, weight, waist circumference and hip circumference) were taken with the subjects wearing indoor clothes and no shoes. Body mass index (BMI) was calculated as weight (kg)/height (m)^2. Waist-to-hip ratio (WHR) was computed as waist circumference divided by hip circumference. Normal weight was defined as BMI = 20–24.9 kg m^{-2}, overweight as BMI = 25–29.9 kg m^{-2} and obesity as BMI $\geq$ 30 kg m^{-2}.

Dietary survey

Dietary intake was assessed by use of the 3-day recall method. It was used to define and quantify food intake during the previous 72 hours, not including weekend days. Common sets of household measures and photographs and/or drawings of commonly used foods were shown to the participants to help them estimate food portion sizes. Probing questions about snacks, drinks, type of milk, fat and other foods were used to elicit more information. The nutrient quantities were calculated with a software program (Nutritionist V) provided by Hong Kong University.

Biochemical analyses

Overnight fasting blood was withdrawn from the antecubital vein of each subject for the preparation of serum. Erythrocytes were analysed for superoxide dismutase (SOD) activity using the method of xanthine oxidase[13]. Briefly, cytochrome C (10 μmol l^{-1}) reduction was measured after 30 s of incubation at 25°C with 50 μmol l^{-1} xanthine and 2.5 μmol l^{-1} xanthine oxidase in 50 mmol l^{-1} potassium phosphate buffer (pH 7.8). Absorption at 550 nm was recorded continuously on a Shimazu Multi-Purpose 5000 spectrophotometer (Shimadzu, Kyoto, Japan).

Serum triglycerides (TG), total cholesterol (TC), low-density lipoprotein cholesterol (LDL-C), high-density lipoprotein cholesterol (HDL-C), apolipoprotein AI (apo A) and apolipoprotein B (apo B) were measured with a Hitachi Automatic Analyzer (Tokyo, Japan). Serum TG concentrations were assayed by hydrolysing the triglycerides and measuring the released glycerol. Serum TC was determined by using a cholesterol esterase and cholesterol oxidase assay[14]. Serum concentrations of HDL-C were assayed by the same method, as was serum TC after removing LDL-C and very-low-density lipoprotein cholesterol (VLDL-C) with magnesium dextran sulfate. Serum LDL concentrations were calculated according to the Friedewald formula[15], which assumes that circulating VLDL consists of 80% triglycerides and 20% cholesterol. Apo A and apo B were determined by the turbidity immunoassay method.

Malondialdehyde (MDA) in serum was measured by the thiobarbituric acid reaction using high-performance liquid chromatography with a C18 column and ultraviolet–visible detector, and tetraethoxypropane was used as standard[16].

Serum insulin was analysed by radioimmunoassay. The analytical kit was provided by Nanjing Jiancheng Bioengineering Institute in China. Fasting insulin resistance index (FIRI) was a multiplication value of fasting insulin and fasting blood glucose by 25.

Physical activity

Habitual physical activity was evaluated by the modified MOSPA questionnaire developed by the US Centers of Disease Control and Prevention[17,18]. A questionnaire on the status of physical activity was completed by individuals, which included the frequency, duration and intensity of each habitual physical activity for occupational physical activity (OPA), leisure-time physical activity (LPA) and household physical activity (HPA) during the past half year. Subjects were asked to clarify their paid or voluntary job into sedentary work, standing work, manual work or heavy manual work. For LPA, subjects estimated the amount of time spent in walking, cycling, gardening, do-it-yourself activities, sports and housework. The measure for the intensity of leisure-time physical activity was based on the metabolic equivalent (MET) values of the self-reported activities. The total physical activity was expressed as energy expenditure score (EES, kcal kg^{-1} day^{-1}). It was calculated by multiplying the frequency and average

Table 1 Median and boundary values of different grades of physical activity index by cluster analysis in healthy Chinese women

		Low	Moderate	High
TPA	*n*	381	287	93
	Total EE			
	median	8.54	9.90	12.10
	(quartile)	(8.02–9.06)	(9.35–10.46)	(11.47–13.08)
	Boundary value	<9.20	9.20–10.97	>10.97
LPA	*n*	581	142	38
	Leisure-time EE			
	median	0	0.81	2.04
	(quartile)	(0–0.19)	(0.63–1.05)	(1.76–2.60)
	Boundary value	<0.41	0.41–1.41	>1.41
OPA	*n*	434	244	83
	Occupational EE			
	median	3.961	5.91	8.74
	(quartile)	(3.23–4.54)	(5.42–6.38)	(7.90–9.87)
	Boundary value	<4.98	4.98–7.14	>7.14
HPA	*n*	388	336	37
	Household EE			
	median	1.96	3.45	7.03
	(quartile)	(1.49–2.37)	(2.99–4.06)	(6.03–8.27)
	Boundary value	<2.68	2.68–5.04	>5.04

TPA – total physical activity; LPA – leisure-time physical activity; OPA – occupational physical activity; HPA – household physical activity.
EE – energy expenditure (MJ day^{-1}) calculated by multiplying energy expenditure score by the body weight of individual (kg).

duration of each type of physical activity reported by a coefficient estimating the rate of energy cost and the seasonal duration of each activity. The index constructed was used to divide the subjects into high, moderate and low physical activity groups according to the total amount of daily energy expenditure, by multiplying EES by the body weight of the individual (Table 1).

Statistical analysis

The data are expressed as mean ± standard deviation. Statistical analyses were carried out using the Statistical Package for Social Sciences (SPSS) software, version 10.0. Results were compared by analysis of variance (ANOVA) to determine the differences between groups. Differences were determined by one-way ANOVA coupled with the Student–Newman–Keuls multiple comparison test. Differences with $P < 0.05$ were considered significant.

Results

Table 2 shows that BMI was higher in the group aged 45–54 years than in the 35–44 year age group ($P < 0.05$). WHR also increased with age. The intakes of total dietary energy, total dietary fat, total dietary cholesterol, monounsaturated fatty acids and polyunsaturated fatty acid were higher in the 45–54-year-olds than other age groups. The vitamin E and vitamin C intakes were higher in the 55–65 year age group than in other groups ($P < 0.05$).

The concentrations of blood cholesterol, TG, apo A and apo B increased with age ($P < 0.05$). The erythrocyte SOD activity, serum total antioxidant capacity (TAOC), FIRI and the ratios SOD/MDA and TAOC/MDA also increased with age ($P < 0.05$) (Table 3).

The SOD activity of erythrocytes, serum MDA and serum TAOC increased with total physical activity energy

Table 2 Daily dietary nutrient intakes by age group in healthy Chinese women (mean ± standard deviation)

	35–44 years ($n = 168$)	45–54 years ($n = 103$)	55–65 years ($n = 31$)	Total/mean ($n = 302$)
Energy (MJ)	7.23 ± 0.90^a	8.03 ± 1.25^b	7.17 ± 0.90^a	7.49 ± 1.10
Total fat (g)	51.08 ± 7.54^a	56.79 ± 11.24^b	53.19 ± 10.08^c	53.15 ± 9.50
Cholesterol (mg)	206.09 ± 46.35^a	230.38 ± 68.17^b	225.18 ± 75.86^b	215.76 ± 58.35
Saturated fat (g)	11.17 ± 2.38^a	13.11 ± 3.46^b	18.64 ± 11.00^b	12.65 ± 7.52
Monounsaturated fat (g)	18.76 ± 3.27^c	23.25 ± 4.98^a	19.90 ± 5.72^b	20.35 ± 4.63
Polyunsaturated fat (g)	17.30 ± 3.79^a	19.42 ± 5.64^b	18.53 ± 3.30^b	18.11 ± 4.56
Saturated/unsaturated fat	0.31 ± 0.05^a	0.31 ± 0.05^a	0.47 ± 0.25^b	0.33 ± 0.07
Vitamin E (mg)	17.00 ± 14.36^a	16.48 ± 19.31^a	26.84 ± 19.68^b	17.68 ± 16.85
Vitamin C (mg)	115.94 ± 34.84^a	127.74 ± 43.01^b	153.97 ± 79.92^c	123.10 ± 44.44
Carotene (μg RE)	3420.61 ± 447.91^a	3736.12 ± 960.93^a	2762.51 ± 113.11^b	3468.88 ± 744.30
BMI (kg m^{-2})	22.68 ± 3.01^a	23.75 ± 3.04^b	23.81 ± 3.01^b	23.13 ± 3.07
WHR	0.79 ± 0.05^a	0.81 ± 0.05^b	0.85 ± 0.09^c	0.80 ± 0.07

RE – retinol equivalents; BMI – body mass index; WHR – waist-to-hip ratio.
Different superscript letters denote significant differences in the row at $P < 0.05$ (one-way analysis of variance, multiple comparison by Student–Newman–Keuls test).

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Table 3 Serum lipids, oxidative stress status and FIRI by age group in healthy Chinese women (mean ± standard deviation)

Age group (years)	Cholesterol (mmol l^{-1})	TG (mmol l^{-1})	Apo A (mmol l^{-1})	Apo B (mmol l^{-1})	Apo A/apo B	Erythrocyte SOD activity (NU/g Hb)	Serum MDA (nmol l^{-1})	Serum TAOC (IU ml^{-1})	SOD/MDA	TAOC/MDA	FIRI
35–44 (n = 444)	5.17 ± 0.49^{a}	0.89 ± 0.38^{a}	1.20 ± 0.15^{a}	0.77 ± 0.08^{a}	1.60 ± 0.21^{a}	20.25 ± 2.83^{a}	7.74 ± 1.67^{a}	17.05 ± 2.28^{a}	2.77 ± 1.02^{a}	2.35 ± 0.97^{a}	1.99 ± 0.56^{a}
45–54 (n = 252)	5.65 ± 0.58^{b}	1.24 ± 0.46^{b}	1.26 ± 0.19^{b}	0.85 ± 0.10^{b}	1.49 ± 0.27^{b}	20.03 ± 2.32^{a}	8.30 ± 2.00^{b}	16.30 ± 2.18^{b}	2.60 ± 1.11^{b}	2.13 ± 1.03^{b}	2.39 ± 0.77^{b}
55–65 (n = 65)	6.28 ± 0.57^{c}	1.53 ± 0.38^{c}	1.57 ± 0.24^{c}	0.86 ± 0.08^{b}	1.83 ± 0.26^{c}	18.95 ± 2.08^{b}	8.80 ± 1.55^{c}	16.09 ± 2.07^{b}	2.28 ± 0.87^{c}	1.92 ± 0.66^{b}	2.66 ± 0.74^{b}
Total (n = 761)	5.43 ± 0.63	1.06 ± 0.46	1.25 ± 0.20	0.80 ± 0.10	1.57 ± 0.25	20.06 ± 2.64	8.02 ± 1.80	16.72 ± 2.26	2.67 ± 1.05	2.24 ± 0.98	2.18 ± 0.69

TG – triglycerides; apo A – apoliporotein AI; apo B – apolipoprotein B; SOD – superoxide dismutase; MDA – malondialdehyde; TAOC – total antioxidant capacity; FIRI – fasting insulin resistance index.
Different superscript letters denote significant difference in the column at $P < 0.05$ (one-way analysis of variance, multiple comparison by Student–Newman–Keuls test).

expenditure (TPA) after adjusting for the factors age, menopausal status, dietary caloric intake, antioxidant intake and dietary fatty acid composition (Table 4).

The adjusted mean values of FIRI, TC and apo B were lowest, whereas apo A was highest, in the moderate group of TPA. The serum apo B level was higher in the low LPA group. TG concentration was highest in the low group of TPA (Table 5).

The antioxidant capacity indices, such as SOD activity of erythrocytes, serum TAOC and TAOC/MDA ratio, increased with increasing LPA. The adjusted mean values of FIRI decreased with increasing LPA. After controlling for confounding variables, erythrocyte SOD activity and serum MDA levels increased significantly with the OPA energy expenditure score. Compared with the low OPA group, the SOD/MDA ratio, TAOC and MDA levels were higher in the moderate and high OPA groups. FIRI and TC were lowest and apo A was highest in the moderate OPA group. In terms of HPA, the SOD activity of erythrocytes increased with HPA energy expenditure. TG was significantly lowest in the high HPA group. Apo B content was higher in the low HPA group.

After adjusting for confounders, in comparison with the low BMI group, serum TAOC was higher in the moderate and high BMI groups ($P < 0.05$). The adjusted mean values of FIRI and TG increased significantly with increasing BMI ($P < 0.05$).

After controlling for factors such as age, menopausal status, BMI, TPA energy expenditure and dietary antioxidant intake, triglycerides and apo B were positively related to FIRI. The ratios of SOD/MDA and TAOC/MDA were inversely associated with FIRI ($P < 0.05$) (Table 6).

Discussion

The present study shows that serum TAOC and erythrocyte SOD activity increased with the increase of total exercise energy expenditure, without significant changes in serum MDA, in healthy Chinese females. The elevated antioxidant capacity plays a meaningful role in protecting from injury by reactive oxygen species (ROS). Exercise is able to produce ROS which, in turn, initialise or stimulate the body's antioxidant system to scavenge the ROS. A study conducted by Brites *et al.*[19] showed that plasma antioxidant capacity increased by 25% in athletes with regular physical training. The present study suggests that a long-term, certain level of exercise is able to promote the antioxidant capacity *in vivo*, since subjects in the present study pursued a level of exercise that was significantly lower than that of athletes.

Most studies on the relationship between physical activity and oxidative stress focus on the influence of exercise on oxidative stress and only a few studies emphasise the relationship between occupational or household work and oxidative stress[20,21]. Some studies have shown that physical activity from occupational work

Table 4 Adjusted values of oxidative stress indices by different grades of physical activity index and obesity levels in healthy Chinese women (mean ± standard deviation)

	Grade	Erythrocyte SOD activity (NU/g Hb)	Serum MDA (nmol l^{-1})	TAOC (IU ml^{-1})	SOD/MDA	TAOC/MDA
TPA*	Low	18864 ± 121[a]	7.75 ± 0.09[a]	16.50 ± 0.12	2598 ± 54	2.27 ± 0.05
	Moderate	20949 ± 138[b]	8.20 ± 0.10[b]	16.97 ± 0.13	2739 ± 62	2.25 ± 0.06
	High	22275 ± 245[c]	8.50 ± 0.18[b]	16.77 ± 0.25	2756 ± 110	2.07 ± 0.10
	P-value	0.00	0.00	0.13	0.18	0.20
LPA†	Low	19935 ± 102[a]	7.96 ± 0.07	16.72 ± 0.09	2671 ± 44	2.26 ± 0.04[a]
	Moderate	20428 ± 210[b]	8.24 ± 0.15	16.43 ± 0.19	2620 ± 90	2.09 ± 0.08[a]
	High	20790 ± 417[b]	8.00 ± 0.3	17.98 ± 0.38[ab]	2857 ± 119	2.46 ± 0.17[b]
	P-value	0.03	0.25	0.00	0.48	0.04
OPA‡	Low	19331 ± 121[a]	7.85 ± 0.09[a]	16.62 ± 0.11	2572 ± 51[a]	2.20 ± 0.05
	Moderate	20687 ± 160[b]	8.17 ± 0.11[b]	16.90 ± 0.14	2820 ± 67[b]	2.35 ± 0.06
	High	22104 ± 278[c]	8.40 ± 0.20[c]	16.85 ± 0.25	2750 ± 118[b]	2.10 ± 0.11
	P-value	0.00	0.01	0.28	0.01	0.07
HPA§	Low	19772 ± 124[a]	7.96 ± 0.09	16.66 ± 0.11	2665 ± 53	2.24 ± 0.06
	Moderate	20228 ± 133[b]	8.00 ± 0.10	16.80 ± 0.12	2649 ± 57	2.21 ± 0.06
	High	21737 ± 408[c]	8.63 ± 0.29	16.85 ± 0.37	2931 ± 174	2.50 ± 0.24
	P-value	0.00	0.09	0.66	0.30	0.37
BMI¶	Low	20.08 ± 131	8.06 ± 0.09	17.19 ± 0.22[a]	2645 ± 56	2.19 ± 0.05
	Moderate	20.06 ± 135	7.89 ± 0.10	16.83 ± 0.12[b]	2724 ± 58	2.29 ± 0.05
	High	20.06 ± 245	8.20 ± 0.18	16.53 ± 0.12[b]	2588 ± 105	2.23 ± 0.10
	P-value	0.99	0.23	0.03	0.43	0.47

SOD–superoxide dismutase; MDA–malondialdehyde; TAOC–total antioxidant capacity; TPA – total physical activity; LPA – leisure-time physical activity; OPA – occupational physical activity; HPA – household physical activity; BMI – body mass index.

Different superscript letters denote significant differences at $P < 0.05$ level (General Linear Model covariate analysis, multiple comparison by Student–Newman–Keuls test).

* Adjusted factors for *total physical activity energy expenditure* include age, menopausal status, tea, BMI, dietary energy and cholesterol intakes, dietary fatty acid composition and antioxidant vitamins.

† Adjusted factors for *leisure-time physical activity energy expenditure* include age, menopausal status, tea, BMI, occupational and household physical activity energy expenditures, dietary energy and cholesterol intakes, as well as dietary antioxidants.

‡ Adjusted factors for *occupational physical activity energy expenditure* include age, menopausal status, tea, BMI, leisure-time and household physical activity energy expenditures, dietary energy and cholesterol intakes, as well as dietary antioxidants.

§ Adjusted factors for *household physical activity energy expenditure* include age, menopausal status, tea, BMI, occupational and leisure-time physical activity energy expenditures, dietary energy and antioxidant intakes.

¶ Adjusted factors for *BMI* include age, menopausal status, family history, total physical activity energy expenditure, dietary energy and antioxidant intakes.

makes up a large portion of total physical activity. Some studies have revealed that a low level of occupational physical activity is related to higher oxidative stress *in vivo*. But the results on the relationship between levels of physical activity and CVD incidence are inconsistent. The present study shows that moderate physical activity from household and occupational work in terms of energy expenditure is related to elevated erythrocyte SOD activity and higher serum SOD/MDA ratio. But serum SOD/MDA was lowered in the highest level of energy expenditure from household and occupational work. These findings suggest that antioxidant capacity is positively related to certain levels of occupational physical activity. Excessive physical activity is unable to stimulate the production of erythrocyte SOD activity or other antioxidant components to control ROS or MDA. Excessive physical activity is related not only to the production of ROS, but also to the psychological pressure in China, which could depress the action of the antioxidant system.

When controlling for the factors of age, menopausal status, exercise and occupational energy expenditure, there is a positive association between energy expenditure from housework and erythrocyte SOD activity. This suggests that housework, as one of the daily physical activities, is beneficial to the improvement of antioxidant capacity at least in China.

There are several studies on the influence of exercise on insulin sensitivity in diabetic patients, but only a few studies in healthy populations. The present results in healthy females provide evidence that the insulin resistance index decreased with increasing exercise. A series of investigations supports the beneficial role of exercise in improvement of insulin resistance[22,23]. The mechanism of this action might be related to decreasing accumulation of fat in the abdomen, stimulating the phosphorylation of glucose and promoting the utilisation of glucose in peripheral tissue such as skeletal muscle[24,25].

We found that FIRI was lowest in females with moderate energy expenditure from occupational work, but increased in subjects with a high energy expenditure in occupational work. This indicates that occupational physical activity at certain levels is meaningful in decreasing the FIRI. However, the FIRI increased when the occupational physical activity exceeded a certain level, which did not result in improvement of insulin sensitivity.

A large number of studies have shown the beneficial role of exercise in lipid metabolism[25,26]. Physical exercise is reported to elevate plasma HDL and decrease LDL concentrations in males and females[27]. However, this change in HDL and LDL by physical exercise is much more obvious in males than in females. One study showed that physical exercise in postmenopausal women had no effect

Table 5 Adjusted values of FIRI and serum lipids by different grades of physical activity index and obesity levels in healthy Chinese women (mean ± standard deviation)

	Grade	FIRI	TC ($mmol\,l^{-1}$)	TG ($mmol\,l^{-1}$)	Apo A ($mmol\,l^{-1}$)	Apo B ($mmol\,l^{-1}$)
TPA*	Low	2.43 ± 0.07[a]	5.51 ± 0.03[a]	1.13 ± 0.02[a]	1.25 ± 0.01[a]	0.82 ± 0.01[a]
	Moderate	2.00 ± 0.04[b]	5.29 ± 0.03[b]	1.01 ± 0.02[b]	1.27 ± 0.01[b]	0.78 ± 0.01[b]
	High	2.26 ± 0.03[c]	5.37 ± 0.06[b]	0.95 ± 0.04[c]	1.20 ± 0.02[ac]	0.81 ± 0.01[ac]
	P-value	0.00	0.00	0.00	0.00	0.00
LPA†	Low	2.18 ± 0.03[a]	5.43 ± 0.02	1.07 ± 0.02	1.25 ± 0.01	0.81 ± 0.00[a]
	Moderate	2.07 ± 0.06[b]	5.43 ± 0.05	1.06 ± 0.04	1.27 ± 0.02	0.78 ± 0.01[b]
	High	1.90 ± 0.12[c]	5.30 ± 0.09	0.96 ± 0.07	1.28 ± 0.03	0.79 ± 0.02[b]
	P-value	0.04	0.36	0.34	0.33	0.01
OPA‡	Low	2.18 ± 0.03[a]	5.46 ± 0.03[a]	1.09 ± 0.02[a]	1.24 ± 0.01[a]	0.81 ± 0.00
	Moderate	2.04 ± 0.04[b]	5.35 ± 0.03[b]	1.06 ± 0.03[a]	1.29 ± 0.01[b]	0.79 ± 0.01
	High	2.27 ± 0.08[ac]	5.45 ± 0.06[ac]	0.90 ± 0.05[b]	1.20 ± 0.02[ac]	0.80 ± 0.01
	P-value	0.01	0.02	0.00	0.00	0.10
HPA§	Low	2.19 ± 0.03	5.46 ± 0.03	1.09 ± 0.02[a]	1.26 ± 0.01	0.82 ± 0.00[a]
	Moderate	2.11 ± 0.04	5.37 ± 0.03	1.04 ± 0.02[a]	1.24 ± 0.01	0.79 ± 0.01[a]
	High	2.03 ± 0.12	5.48 ± 0.09	0.95 ± 0.07[b]	1.29 ± 0.03	0.80 ± 0.02[b]
	P-value	0.18	0.07	0.04	0.10	0.03
BMI¶	Low	2.11 ± 0.04[a]	5.40 ± 0.03	1.02 ± 0.02[a]	1.24 ± 0.01	0.80 ± 0.01
	Moderate	2.20 ± 0.04[b]	5.44 ± 0.03	1.07 ± 0.02[a]	1.26 ± 0.01	0.81 ± 0.01
	High	2.33 ± 0.07[c]	5.43 ± 0.06	1.15 ± 0.04[b]	1.26 ± 0.02	0.80 ± 0.01
	P-value	0.01	0.59	0.02	0.12	0.24

TC – total cholesterol; TG – triglycerides; apo A – apoliporotein AI; apo B – apolipoprotein B; TAOC – total antioxidant capacity; FIRI – fasting insulin resistance index; TPA – total physical activity; LPA – leisure-time physical activity; OPA – occupational physical activity; HPA – household physical activity; BMI – body mass index.
Different superscript letters denote significant differences at $P < 0.05$ level (General Linear Model covariate analysis, multiple comparison by Student–Newman–Keuls test).
* Adjusted factors for *total physical activity energy expenditure* include age, menopausal status, tea, BMI, dietary energy and cholesterol intakes, dietary fatty acid composition and antioxidant vitamins.
† Adjusted factors for *leisure-time physical activity energy expenditure* include age, menopausal status, tea, BMI, occupational and household physical activity energy expenditures, dietary energy and cholesterol intakes, as well as dietary antioxidants.
‡ Adjusted factors for *occupational physical activity energy expenditure* include age, menopausal status, tea, BMI, leisure-time and household physical activity energy expenditures, dietary energy and cholesterol intakes, as well as dietary antioxidants.
§ Adjusted factors for *household physical activity energy expenditure* include age, menopausal status, tea, BMI, occupational and leisure-time physical activity energy expenditures, dietary energy and antioxidant intakes.
¶ Adjusted factors for *BMI* include age, menopausal status, family history, total physical activity energy expenditure, dietary energy and antioxidant intakes.

on plasma HDL concentration. It was postulated that the sensitivity of lipid metabolism to physical exercise in females is less that in males. The influence of oestrogens on lipid metabolism might contribute to this phenomenon[28].

There is still debate on the relationship between occupational physical activity and blood lipids. Assanelli *et al.*[29] have reported that physical activity in pastimes is related to improvements of plasma TC, TG and HDL concentrations, but there is no beneficial influence on lipid metabolism related to occupational physical activity, even when the latter is high. In contrast, Wibur *et al.*[30] found that a high score of occupational physical activity was positively related to plasma HDL concentration and negatively related to plasma cholesterol concentration in females. Thus occupational physical activity is beneficial to cardiovascular health. We found that a moderate level (less than 1700 kcal day^{-1}) of occupational physical activity was related to high plasma HDL and low cholesterol concentrations in females after adjusting for several factors such as age, menopausal status, exercise, housework and dietary factors. This also supports the beneficial effect on lipid metabolism derived from occupational physical activity at certain levels.

There are no studies reporting the influence of physical activity as household work on CVD risk factors. We found that plasma apo B and TG were lowered in females who had high energy expenditure from household work. Heavy household work did not benefit cardiovascular health due to decreased leisure-time physical exercise and increased psychological stress in a previous study[31]. The level of household work in the females in our study did not probably reach the level that has a harmful effect on the cardiovascular system.

The multiple regression analysis of our study showed that FIRI was related to antioxidant status, obesity index,

Table 6 Partial correlation analysis among insulin resistance, erythrocyte SOD activity, serum lipids and oxidative stress in healthy Chinese women

Item	FIRI	*P*-value
SOD	−0.01	0.87
MDA	0.03	0.49
TAOC	−0.10	0.01
SOD/MDA	−0.10	0.01
TAOC/MDA	−0.14	0.00
TC	0.18	0.00
TG	0.09	0.01
Apo A	−0.00	0.91
Apo B	0.20	0.00
Apo A/apo B	−0.13	0.00

FIRI – fasting insulin resistance index; SOD – superoxide dismutase; MDA – Malondialdehyde; TAOC – total antioxidant capabililty; TC – total cholesterol; TG – triglycerides; apo A – apolipoprotein AI; apo B – apolipoprotein B.

heredity and physical activity. The insulin sensitivity was lower with age, elevated BMI and plasma lipid concentration, lowered antioxidant capacity and less exercise. A series of studies has revealed that FIRI increases with increasing age[32]. In particular, FIRI increased in postmenopausal females owing to the lack of female hormones[33]. We found that FIRI was reversibly associated with antioxidant status after adjusting for age, menopausal status, BMI, physical activity and dietary factors. This indicates that decreased insulin sensitivity is positively associated with increased oxidative stress in healthy females. A large number of studies have provided evidence that elevated insulin resistance accelerates the production of ROS, which in turn aggravates insulin resistance. It is well known that insulin plays an important role in the regulation of lipid metabolism, by inhibiting the catalysis of lipids and promoting lipoprotein synthesis. We found that FIRI in Chinese females was positively associated with serum TG, cholesterol and apo B, and negatively associated with apo A/apo B ratio. This suggests that high FIRI is related with unhealthy lipid profiles as, obviously, also are CVD risk factors.

In conclusion, the present study shows that physical activity is related to serum lipid concentrations and insulin resistance, the grade of energy expenditure from exercise being positively related to antioxidant capacity and insulin sensitivity. Energy expenditure from occupational physical activity of less than 1700 kcal day^{-1} benefits antioxidant capacity and insulin sensitivity. However, heavy occupational physical activity may be harmful to the cardiovascular system.

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