RISK OF DYSLIPIDEMIA IN RELATION TO LEVEL OF PHYSICAL ACTIVITY AMONG THAI PROFESSIONAL AND OFFICE WORKERS

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Abstract. We completed a cross-sectional study of 1,608 Thai participants (536 men and 1,072 women) receiving annual health check-ups to evaluate the relation between physical activity levels and fasting serum concentrations of total cholesterol (TCH), triglyceride (TG), high density lipoprotein-cholesterol (HDL-C), and the total cholesterol: high density lipoprotein-cholesterol (TCH:HDL-C) ratio. Physical activity levels were assessed using a self-administered questionnaire administered at the time of blood collection. After controlling for confounders, men who reported high physical activity levels had on average a 3.42 mg/dl higher (p=0.020) in HDL-C concentrations, when compared to men who reported low physical activity levels. Higher mean HDL-C concentrations were also observed for women who reported high physical activity levels, when compared with their less active counterparts (4.24 mg/dl, p=0.004). TG concentrations were 30.92 mg/dl lower in men (p=0.029) and 12.83 mg/dl lower in women (p=0.003) who had high physical activity levels when compared with less active individuals. Men who reported high physical activity levels, compared with those who reported low physical activity levels, had a 59% reduction in risk for hypertriglyceridemia (OR=0.41, 95% CI: 0.24-0.70). The corresponding OR for women was 0.43 (95%CI: 0.21-0.88). No association was found between physical activity levels and TCH concentrations. Overall, these data suggest that habitually active men and women are less likely to have hypertriglyceridemia and low HDL-C concentrations. The favorable effects of physical activity on lipid and lipoprotein concentrations are consistent with the evidence documenting the cardiovascular health benefits of physically active lifestyles.

INTRODUCTION

A large epidemiological, clinical, and experimental literature clearly points to favorable physiological changes and overall health benefits associated with regular physical activity (DHHS, 1996). Benefits include favorable alterations in plasma lipid and lipoprotein concentrations, systolic and diastolic blood pressures, endothelial function, glycemic control, reductions in risk of essential hypertension, coronary heart disease, type 2 diabetes and certain cancers, as well as increased longevity (DHHS, 1996). On the basis of this substantial body of scientific evidence, the US Centers for Disease Control and Prevention and the American College of Sports Medicine have recommended that adults should accumulate 30 minutes or more of moderate-in-

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tensity physical activity on most, and preferably all, days of the week. Moderate intensity physical activity is defined as activity with an energy requirement of 3-5 metabolic equivalents (METs). For a typical healthy adult, this is equivalent to brisk walking at 3-4 miles per hour. In 2002, the Institute of Medicine noted that at least 60 minutes of moderate-intensity physical activity are necessary to prevent weight gain, achieve a higher level of physical fitness, and obtain the full health benefits of activity (IOM, 2002). That same year, recognizing the burden of chronic disease, and the global public health importance of combating physical inactivity, WHO adopted a resolution to provide leadership to encourage physical activity within in their broader framework for chronic disease prevention and health promotion (WHO, 2002). Hence, guidelines promoted by several health organizations endorse moderate and/or high intensity levels of physical activity of varying durations as a health promotion and disease prevention modality for the general adult population.

Results from clinical studies suggest that hypertension, chronic systemic inflammation, dyslipidemia and oxidative stress are common pathophysiologic features of cardiovascular disorders (Johnstone *et al*, 1996; Poulter, 1999; Dhalla *et al*, 2000; Lopes *et al*, 2003). Taken together with evidence from observational studies, controlled clinical trials, and animal studies, suggests that physical activity may impact the occurrence of cardiovascular disease through a number of overlapping and independent biological pathways. For instance, evidence from studies primarily conducted in North America and Europe indicate that physiological effects of physical activity include improved insulin sensitivity, reduced blood pressure, decreased concentrations of pro-inflammatory cytokines in peripheral circulation, reduced oxidative stress and improved plasma lipid and lipoprotein concentrations (Mayer-Davis *et al*, 1998; Smith *et al*, 1999; He and Bazzano, 2000; Durstine *et al*, 2001; Yeo and Davidge, 2001; Kraus *et al*, 2002; Halverstadt *et al*, 2007; Slentz *et al*, 2007). For example, Kobayashi *et al* (2006) recently reported that modest increases in habitual walking are associated with reduced TG concentrations among Japanese men. Although several investigators have evaluated influences of lifestyle characteristics on metabolic parameters in Thai adults, none has assessed the extent to which, if at all, habitual physical activity is associated with favorable lipid profiles among Thai men and women. To fill this gap in knowledge, we completed a cross-sectional study to evaluate the relation between levels of physical activity and fasting plasma concentrations of total cholesterol (TCH), triglyceride (TG), high density lipoprotein-cholesterol (HDL-C), and the total cholesterol: high density lipoprotein-cholesterol ratio (TCH:HDL-C) among Thai professional and office workers who took part in annual clinical examinations.

MATERIALS AND METHODS

Study population and data collection

We conducted a cross-sectional study of 1,608 subjects (536 men and 1,072 women) who participated in annual health examinations at the Mobile Health Checkup Unit of King Chulalongkorn Memorial Hospital in Bangkok, Thailand during the period of December 2006 through February 2007. Each year, Chulalongkorn Memorial Hospital provides on-site annual health examinations to professional and office workers of approximately 45 private companies and governmental agencies in and around Bangkok. Given that blood chemistry are not routinely measured on all participants under the age of 35 years, this research was restricted to those participants who were ≥35 years of age at the time of annual health examination. Eligible participants were asked to provide information about their age, marital status, occupation, educational attainment, medical history, smoking status, and alcohol consumption habits. Information concerning physical activity was collected using a self-administered Global Physical Activity Questionnaire (GPAQ). The questionnaire, developed and validated by the World Health Organization (WHO) (2004), measures three physical activity domains: occupational activity, leisure time physical activity, and purposeful activity for transportation (*eg*, walking or cycling to work). Participants underwent routine physical examinations which including determining their height, weight, and collecting an overnight fasting venous blood sample. Standing height was measured without shoes to the nearest 0.5 centimeter. Weight was determined without shoes and with participants lightly clothed. Weight was measured using an automatic electronic scale (Seca, Hamburg, Germany) to the nearest 100 grams.

Laboratory analyses

Serum samples were used to determine participants' lipid and lipoprotein profiles. Serum triglyceride (TG) and total cholesterol (TCH) concentrations were determined using standardized enzymatic procedures. TG was analyzed by glycerol phosphate oxidase assay. TCH was quantified using the Trinder endpoint reaction in an automatic chemistry analyzer. High density lipoprotein-cholesterol (HDL-C) was measured by a chemical precipitation technique using dextran sulfate. All laboratory assays were completed without knowledge of participants' medical history. Lipid and lipoprotein concentrations were reported as mg/dl.

All participants provided informed consent and the research protocol was reviewed and approved by the Ethics Committee of the Faculty of Medicine, Chulalongkorn University, and the Division of Human Subjects Research, University of Washington.

Analytical variable specification

Physical activity data were coded using previously described procedures (WHO, 2004). Participants were classified into three categories of total physical activity (high, moderate and low). The criteria for high physical activity participation were 3,000 MET (Metabolic Equivalent) minutes per week accumulated over 7 days or 1,500 MET minutes of vigorous-intensity activity accumulated over 3 days or more. Moderate physical activity participation was classified as 30 minutes of walking or moderate-intensity activity on 5 or more days, 20 minutes of vigorous-intensity activity on 3 or more days, or 600-2,999 total MET minutes of activity over 7 days. Those not meeting the criteria for either high or moderate levels of physical activity were classified as low physical activity participation. Participant's body mass index (BMI) was calculated by expressing weight (kilograms) divided by height (meters) squared. BMI was evaluated both as a continuous variable and as a categorical variable. We used the criteria proposed by WHO (1995) to classify participants as lean (BMI < 18.5 kg/m^2), normal (18.5-24.9 kg/m^2), overweight (25.0-29.9 kg/m^2), and obese (≥30 kg/m^2), respectively. We categorized participants' age according to decade (<40, 40-49, 50-59, ≥60 years). Other covariates were categorized as follows: education (<bachelor degree, bachelor degree, master degree, and PhD degree); cigarette smoking history (never, previous and current smoker); alcohol consumption (non-current and current).

Using the criteria of the National Cholesterol Education Program (NCEP) Adult Treatment Panel III (ATP III), high total cholesterol is defined as TCH ≥200 mg/dl. Hypertriglyceridemia is defined as TG ≥150 mg/dl. Low HDL-C is defined as HDL-C <40 mg/dl in men and <50 mg/dl in women (NCEP, 2001). We performed analyses separately for TCH, TG and HDL-C expressed as continuous variables. The ratio of TCH and HDL-C is thought to be an integrative measure of dyslipidemia (Lemieux *et al*, 2001). Therefore, we calculated the TCH/HDL-C ratio and repeated all gender-specific analyses using this integrative lipid measure.

Statistical analyses

We first explored frequency distributions of socio-demographic, behavioral characteristics and medical histories. All data were summarized and displayed as number and proportion of participants possessing each characteristic (categorical variables). For continuous variables, we report group-specific means and standard deviations (SD).

We used multivariable least squares linear regression procedures to assess the influence of physical activity on serum lipid and lipoprotein concentrations. Analyses were completed for each lipid marker (*ie*, TCH, TG, HDL-C, and TCH:HDL-C ratio). To assess confounding, we entered covariates into a linear regression model one at a time and then compared coefficients. Final linear regression models included covariates that altered unadjusted coefficients by at least 10%. Adjusted R^2 values, representing the total variation of each lipid marker explained by covariates in final models, were also reported. Since there is no consensus concerning how adiposity should be model in evaluation of physical activity and dyslipidemia, we repeated the analysis after stratify participants according to lean (BMI <25 kg/m^2) and overweight (BMI ≥25 kg/m^2). All analyses were completed separately for male and female patients.

We used logistic regression procedures to estimate the relative risks of having clinically relevant high TCH (≥200 mg/dl), high TG (≥150 mg/dl) concentrations and low HDL-C concentrations (<40 in men and <50 in women) according to their habitual physical activity level (low, moderate and high activity levels). Multivariable logistic regression procedures were employed to calculate odds ratios (OR, measures of relative risk) while adjusting for potential confounding factors. Covariates were evaluated as potential confounding factors on the basis of their hypothesized relationship with high TCH, high TG, low HDL-C, and physical activity status. Confounding was assessed empirically by entering covariates into logistic regression models one at a time, and by comparing adjusted and unadjusted ORs (Rothman and Greenland, 1998). Final logistic regression models included covariates that altered unadjusted ORs by at least 10%. All statistical analyses were performed using SPSS (version 14.0, SPSS, Chicago, IL, USA) software. All reported p-values are two tailed, and confidence intervals were calculated at the 95% level.

RESULTS

Socio-demographic characteristics for male and female participants are presented in Table 1. Overall, this is a well-educated population, with more than 70% of the population having at least a bachelor's degree. We noted a great deal of variability in self-reported habitual physical activity in this study population. Approximately 44% of men reported having low levels of physical activity, while 26% reported high levels of physical activity. Notably, self-reported physical activity levels were much lower among women. Over 51% of these women reported low levels of physical activity with only 14.2% reporting high levels physical activity.

There was no evidence of associations between serum TCH concentrations and physical activity among men and women (Table 2). However, mean TG concentrations decreased across groups of men classified by increasing level of physical activity (p for trend = 0.030). After controlling for potential confounding, we noted that mean TG concentrations were 12.24 mg/dl (p = 0.364) lower among men reporting to have moderate levels of activity, compared with men reporting low levels of activity. Mean TG concentrations

Table 1
Socio-demographic characteristics of study participants.

Characteristics	Men (*N*=536)		Women (*N*=1,072)	
	n[a]	%	*n*[a]	%
Age (Years)				
35-39	124	23.1	171	16.0
40-49	217	40.5	479	44.7
50-59	171	31.9	402	37.5
≥60	24	4.5	20	1.9
Mean (SD)[b]	46.5 (7.6)		47.2 (6.8)	
Education				
Less than bachelor degree	155	29.3	209	19.7
Bachelor degree	106	20.0	437	41.1
Master degree	110	20.8	245	23.1
PhD degree	158	29.9	171	16.1
Cigarette smoking status				
Never smoker	328	61.7	1,009	95.1
Previous smoker	108	20.3	36	3.4
Current smoker	96	18.0	16	1.5
Alcohol consumption status				
Non-current drinker	269	50.5	909	85.8
Current drinker	264	49.5	150	14.2
Body mass index (kg/m^2)				
<18.5	5	0.9	47	4.4
18.5-24.9	301	56.8	652	61.6
25.0-29.9	176	33.2	263	24.9
≥30	48	9.1	96	9.1
Mean (SD)[b]	25.1 (3.5)		24.0 (4.2)	
Level of physical activity				
Low	228	43.6	526	51.1
Moderate	157	30.0	358	34.8
High	138	26.4	146	14.2

[a]Number may not be added up to the total number due to missing data
[b]SD = Standard deviation

were 30.92 mg/dl lower among highly activity men, compared with those reporting low activity ($p = 0.029$). A similar pattern of decreased mean TG concentrations with increasing levels of physical activity was observed among women (p for trend < 0.001). Mean TG concentrations were 10.35 mg/dl lower for women who were moderately active ($p = 0.001$) and 12.83 mg/dl lower for highly active women ($p=0.003$) when compared with women who had low levels of activity. When age, education, cigarette smoking, alcohol consumption and body mass index (BMI) were adjusted for, men who reported high levels of physical activity had HDL-C concentrations that were 3.42 mg/dl higher ($p=0.020$), on average, than concentrations in men who reported low levels of physical activity. Higher

Table 2
Relationships of serum lipids and lipoprotein concentrations with levels of habitual physical activity: estimated linear regression coefficients (b), standard errors (SE), and p-values.

Levels of physical activity	Total cholesterol (mg/dl)		Triglyceride (mg/dl)		HDL-Cholesterol(mg/dl)		Total cholesterol: HDL-C ratio	
	β^a ± SE	p-value	β^a ± SE	p-value	β^b ± SE	p-value	β^c ± SE	p-value
Among men								
Low	Reference		Reference		Reference		Reference	
Moderate	-0.15 ± 4.27	0.971	-12.24 ± 13.48	0.364	0.92 ± 1.40	0.511	-0.10 ± 0.14	0.456
High	3.73 ± 4.48	0.405	-30.92 ± 14.13	0.029	3.42 ± 1.46	0.020	-0.29 ± 0.14	0.043
Trend test p-value	0.439		0.030		0.023		0.045	
Adjusted R^b	1.89%		9.18%		7.62%		8.05%	
	β^a ± SE	p-value	β^d ± SE	p-value	β^a ± SE	p-value	β^c ± SE	p-value
Among women								
Low	Reference		Reference		Reference		Reference	
Moderate	-1.43 ± 2.60	0.583	-10.35 ± 3.16	0.001	3.01 ± 1.07	0.005	-0.20 ± 0.07	0.003
High	-1.97 ± 3.57	0.581	-12.83 ± 4.32	0.003	4.24 ± 1.47	0.004	-0.28 ± 0.09	0.002
Trend test p-value	0.507		<0.001		0.001		<0.001	
Adjusted R^b	5.57%		14.60%		11.57%		13.17%	

[a] Coefficients adjusted for age (categorical), education, cigarette smoking, alcohol consumption and body mass index (categorical)
[b] Coefficients adjusted for age (categorical), education, alcohol consumption and body mass index (categorical)
[c] Coefficients adjusted for age (categorical), education and body mass index (categorical)
[d] Coefficients adjusted for age (categorical), education, cigarette smoking and body mass index (categorical)

Table 3
Odds ratio (OR) and 95% confidence interval (CI) of the risk of dyslipidemia according to levels of physical activity.

Levels of physical activity	High TCH		High TG		Low HDL-C		High TCH:HDL-C Ratio	
	Adjusted OR[a]	(95%CI)	Adjusted OR[b]	(95%CI)	Adjusted OR[a]	(95%CI)	Adjusted OR[c]	(95%CI)
Among men								
Low	1.00	(Reference)	1.00	(Reference)	1.00	(Reference)	1.00	(Reference)
Moderate	0.95	(0.61-1.47)	1.01	(0.63-1.60)	0.85	(0.46-1.58)	1.15	(0.74-1.79)
High	1.28	(0.80-2.06)	0.41	(0.24-0.70)	0.61	(0.30-1.23)	0.76	(0.47-1.22)
Trend Test p-value	0.358		0.003		0.171		0.338	
	Adjusted OR[c]	(95%CI)	Adjusted OR[d]	(95%CI)	Adjusted OR[c]	(95%CI)	Adjusted OR[c]	(95%CI)
Among women								
Low	1.00	(Reference)	1.00	(Reference)	1.00	(Reference)	1.00	(Reference)
Moderate	0.98	(0.74-1.32)	0.72	(0.47-1.10)	0.69	(0.47-1.00)	0.72	(0.52-1.00)
High	0.82	(0.56-1.21)	0.43	(0.21-0.88)	0.63	(0.37-1.07)	0.76	(0.48-1.19)
Trend test p-value	0.400		0.011		0.028		0.077	

High TCH = TCH ≥200 mg/dl; High TG = TG ≥150 mg/dl; Low HDL-C = HDL-C<40 mg/dl in men and HDL-C<50 mg/dl in women; High TCH:HDL-C ratio = TCH:HDL-C ratio >4.5 in men and TCH:HDL-C ratio >4 in women

[a] Adjusted for age (categorical), education, alcohol consumption and body mass index (categorical)

[b] Adjusted for age (categorical), education, cigarette smoking, alcohol consumption and body mass index (categorical)

[c] Adjusted for age (categorical), education and body mass index (categorical)

[d] Adjusted for age (categorical), education, cigarette smoking and body mass index (categorical)

mean HDL-C concentrations were also observed for women who reported high levels of physical activity, when compared with their less active counterparts (4.24 mg/dl, p = 0.004). As shown in Table 2, we also noted that mean values for TCH:HDL-C ratio decreased with increasing levels of physical activity among men and women, respectively (trend test p values both < 0.05).

We next performed logistic regression analyses to evaluate risk of dyslipidemia (elevated TCH, hypertriglyceridemia, reduced HDL-C and elevated TCH:HDL-C ratio) according to varying levels of physical activity. Results from these analyses are summarized in Table 3. Overall, there was no clear evidence of an association between total cholesterol (TCH) concentration and reported levels of physical activity among men. When age, education, smoking, alcohol and BMI were adjusted for, men who reported high levels of physical activity where 59% less likely to have elevated TG (OR=0.41 with 95%CI: 0.24-0.70) compared with men reporting low levels of activity. High levels of physical activity was associated with a 39% reduction in risk of having low HDL-C concentrations (OR=0.61 with 95%CI: 0.30-1.23) and a 24% reduction in risk of having high TCH:HDL-C ratio (OR=0.76 with 95%CI: 0.47-1.22). However, these associations did not reach statistical significance.

Risk of dyslipidemia, particularly hypertriglyceridemia and low HDL-C concentrations, in relation to levels of physical activity were more evident among women. Moderate and high levels of physical activity were associated with a 28% and 57%, respectively, reduction in risk of hypertriglyceridemia among women (Table 3). Physical activity was also inversely related with risk of having low HDL-C concentrations and high TCH:HDL-C ratios.

We also completed analysis stratified by overweight status to evaluate the extent to which the association between physical activity and dyslipidemia may be modified by BMI. Stratified analysis indicated that associations between physical activity and dyslipidemia were not modified by BMI status. Among overweight men, those reported high level of physical activity had a 74% reduced risk of elevated TG compared to men reporting low level of physical activity (95%CI: 0.11-0.59). The corresponding OR for lean men was 0.59 (95%CI: 0.29-1.23). Stratified analysis of lean and overweight women also indicated the absence of effect modification by BMI. The risk of elevated TG was reduced by 52% in overweight women who reported high level of physical activity compared to their overweight counterpart who reported low level of physical activity (OR=0.48, 95%CI: 0.19-1.17). An association of similar and magnitude was observed for lean women (OR=0.34, 95%CI: 0.10-1.18).

DISCUSSION

Using a detailed physical activity questionnaire, we were able to detect associations between physical activity and serum TG and HDL-C concentrations. Men and women who reported high level of physical activity were less likely to have hypertriglyceridemia and low levels of HDL-C compared with those reporting low levels of physical activity. Men who reported high levels of physical activity had on average a 3.42 mg/dl higher HDL-C concentrations when compared to men who reported low levels of physical activity. Higher HDL-C concentrations (4.24 mg/dl) were also observed for women who reported high levels of physical activity, when compared with their less active counterparts. Serum TG concentrations were 30.92 mg/dl lower in men and 12.83 mg/dl lower in women among those who had high levels of activity when compared with less active individuals. Results from our study are largely similar to those reported by investigators who studied other populations (Durstine ***et al***, 2001; Kraus ***et al***, 2002; Kelley *et al*, 2004; Halverstadt *et al*, 2007).

In a review of the published literature, Durstine *et al* (2001) reported that most sedentary persons can experience elevations of 2-3 mg/dl in HDL-C and decreases of 8-20 mg/dl in TG concentrations by increasing energy expenditure to 1,200-2,200 kcal/week. Halverstadt *et al* (2007) also reported that 24-week endurance exercise training induced favorable changes in plasma lipoprotein and lipid profile independent of diet and baseline or change in body fat. For example, with exercise training, serum TG concentrations decreased significantly ($\beta \pm$ SE: -17 ± 3.5 mg/dl, $p<0.001$). Kraus *et al* (2002) in their randomized trial of exercise among sedentary and overweight men and women with dyslipidemia, reported that the highest amount of weekly exercise with minimal weight change had widespread beneficial effects on the lipoprotein profile. In a meta-analysis of randomized controlled trial, Kelly *et al* (2004) reported that aerobic exercise was efficacious for increasing HDL-C (95%CI: 0.1, 3.5 mg/dl) and decreasing TCH (95%CI: -6.9, -1.7), LDL-C (95%CI: -6.5, -2.2) and TG (95%CI: -8.4, -0.1) in women.

Several important limitations must be considered when interpreting the results of our study. First, as the study population was comprised of highly educated middle-aged university employees, the results may not be generalizable to the general Thai population. Second, we used self-reported physical activity to classify study participants. Therefore, we cannot exclude the possibility that some misclassification may have occurred. Further, because of this cross-sectional data collection design, we cannot be certain of the temporal relation between level of physical activity and risk of dyslipidemia. Inferences concerning the protective effect of physical activity and dyslipidemia, however, would be enhanced with data from prospective studies and randomized clinical trials.

In conclusion, our study confirms the favorable effects of physical activity on lipid and lipoprotein concentrations among Thai professional and office workers. These are consistent with the evidence documenting the cardiovascular health benefits of a physically active lifestyle.

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