Available online at www.sciencedirect.com
ScienceDirect
Metabolism Clinical and Experimental 58 (2009) 1347 – 1355
Metabolism
Clinical and Experimental
www.metabolismjournal.com

Association between physical activity and metabolic syndrome in Iranian adults: national surveillance of risk factors of noncommunicable diseases (SuRFNCD-2007)

Alireza Esteghamati[a,*], Omid Khalilzadeh[a], Armin Rashidi[a], Alipasha Meysamie[b], Mehrdad Haghazali[c], Mehrshad Abbasi[a], Fereshteh Asgari[c], Mohammad Mehdi Gouya[c]

[a]*Endocrinology and Metabolism Research Center (EMRC), Vali-Asr Hospital, Tehran University of Medical Sciences, PO Box 13145-784, Tehran, Iran*
[b]*Community of Preventive Medicine, School of Medicine, Tehran University of Medical Sciences, Tehran, Iran*
[c]*Center for Disease Control, Ministry of Health and Medical Education, Tehran, Iran*

Received 6 January 2009; accepted 28 April 2009

Abstract

Metabolic syndrome (MetS) is a common health problem in developing countries. We aimed to assess the association between different aspects of physical activity and MetS in our country. A standardized international questionnaire (Global Physical Activity Questionnaire) recommended by the World Health Organization was used in the third national survey of risk factors of noncommunicable diseases (SuRFNCD-2007) to collect physical activity data from a nationally representative sample of Iranian adults. Physical activity was evaluated in 3 domains: work, commuting, and recreational activities. Both duration and intensity of activity were considered. Biochemical measurements were carried out, and MetS was defined by the International Diabetes Federation and the Adult Treatment Panel III criteria. The data collected from a total of 3296 individuals were analyzed. The national prevalence of MetS was estimated to be between 24% and 30%, depending on sex and the criteria used. The prevalence of MetS among individuals with high-, moderate-, and low-category activity was 18.7% ± 1.5%, 25.8% ± 2.0%, and 27.9% ± 2.0%, respectively ($P < .001$). These rates were 12.6% ± 1.6%, 26.0% ± 1.5%, and 34.1% ± 3.2% among individuals with vigorous activity, with nonvigorous activity, and without activity, respectively ($P < .001$). We demonstrated a significant linear association between the number of metabolic abnormalities and lower levels of various aspects of physical activity (total physical activity, duration of domain-specific activity, and duration of intensity-specific activity; $P < .001$ for all). Notably, the risk for MetS increased 1.28-fold with every 30-min/d reduction in vigorous-intensity activity (95% confidence interval = 1.15-1.42, $P < .001$). The results of the present study should be considered for future public health programs in Iran.

1. Introduction

Metabolic syndrome (MetS) is a cluster of cardiometabolic risk factors including dysglycemia, dyslipidemia, hypertension, and insulin resistance [1]. Besides the well-known growth of obesity, the prevalence of MetS has nearly doubled among normal-weight American adults in a period of only 10 years according to the National Health and Nutrition Examination Surveys in 1988-1994 [2] and 1999-2004 [3]. This health challenge is also becoming a critical problem in developing countries that are heavily influenced by the consequences of modernization and urbanization [4,5]. Recent lifestyle changes in Iran include reductions in the physical activity and replacement of traditional diets by calorie-dense high-fat foods [6]. Metabolic syndrome is therefore an increasingly common condition encountered by our physicians. We recently estimated that 1 of every 4 Tehranian adults has MetS [7]. Genetic factors, diet, physical activity, age, and sex are factors with significant impacts on

* Corresponding author. Tel.: +98 21 88417918; fax: +98 21 64432466.
E-mail addresses: esteghamati@tums.ac.ir (A. Esteghamati), khalilzadeh@razi.tums.ac.ir (O. Khalilzadeh), rasidiarmin@yahoo.com (A. Rashidi), meysamie@tums.ac.ir (A. Meysamie), haghmehr@yahoo.com (M. Haghazali), mehrshad_abbasi@yahoo.com (M. Abbasi), asgarifcdc@yahoo.com (F. Asgari), mgoya57@yahoo.com (M.M. Gouya).

0026-0495/$ – see front matter © 2009 Elsevier Inc. All rights reserved.
doi:10.1016/j.metabol.2009.04.019

predisposition to MetS [8]. Obviously, potentially modifiable risk factors such as physical inactivity are suitable targets for intervention [9,10].

Although many studies have assessed the association between physical activity and MetS [10-18], the association between MetS and different features of physical activity, defined by a standardized international questionnaire, has not been investigated in large population-based studies. In the present study, we assessed for the first time in Iran the association between different aspects of physical activity and the MetS in a nationally representative sample of Iranian adults. Our results, demonstrating significant and novel associations, are important for health policymakers.

2. Materials and methods

2.1. The study population

SuRFNCD-2007 is the third Iranian national survey of risk factors of noncommunicable diseases, which was carried out in 2007. Details of the survey can be found elsewhere [19]. We used the data collected in the survey in the present study. The survey included a cluster sampling scheme by which 4233 Iranian adults aged 25 to 64 years were selected using postal codes across the country. Two men and 2 women were sampled from each age category (15-24, 25-34, 35-44, 45-54, and 55-64 years). Each provincial sample was proportional in size to the total population of that province, for example, 51 (1020 participants) clusters from Tehran (the largest province) and 2 (40 participants) clusters from Ilam (the smallest province). The survey was carried out in collaboration with all 40 universities of medical sciences across the country. The interviewers were trained nurses introduced by medical universities to the managerial team in the national Center for Disease Control. They were trained about the details of performing the interviews (eg, using the Persian translation) in a 1-day workshop in Tehran. Physical examinations were performed by the same nurses. Two of the authors independently checked the quality of data recorded in standardized questionnaires. Blood samples were taken shortly after the interview. Informed consent was obtained from all participants before inclusion in the study. The protocol for both SuRFNCD-2007 and the present study was approved by the Center for Disease Control.

We had 113 individuals with missing data in questionnaires and 28 pregnant women. A total of 796 individuals refused to give blood samples. The data collected from the remaining 3296 individuals were analyzed.

2.2. Physical activity data

The Global Physical Activity Questionnaire (GPAQ) is a standardized questionnaire developed by the World Health Organization to facilitate interpopulation comparisons in epidemiologic studies. We used GPAQ version 2 [20] in our survey. It includes 16 questions about various aspects of physical activity in a typical week. Specifically, physical activity is evaluated in 3 domains: work, travel to and from places, and recreational activities. The evaluation of physical activity in 3 domains is one of the factors that make GPAQ distinct from the less sophisticated, short version of the International Physical Activity Questionnaire [21]. The intensity (ie, vigorous or moderate) of activity in each domain and the time spent on sedentary behaviors (eg, watching TV) are also determined. The questionnaires were administered by interviewers (trained nurses) and in Persian.

Metabolic equivalents (METs), the ratio of a person's working metabolic rate relative to the resting metabolic rate, were used to measure energy expenditure [20]. One MET is the energy cost of sitting quietly and is equivalent to a caloric consumption of 1 kcal/(kg h). Caloric consumption is 4 times as high when being moderately active and 8 times as high when being vigorously active. For the analysis of the GPAQ data, 4 METs are assigned to the time spent in moderate activities and 8 METs to the time spent in vigorous activities to determine overall energy expenditure. Total physical activity (TPA) was calculated by adding all MET × minutes for moderate- or vigorous-intensity physical activity performed at work, commuting, and recreation.

Physical activity was classified as 1 of the 3 categories based on the GPAQ analysis framework:

1. High: a person reaching any of the following criteria is classified in this category:
   - Vigorous-intensity activity on at least 3 days a week achieving a minimum of at least 1500 MET-minutes per week or
   - Seven or more days of any combination of walking and moderate- or vigorous-intensity activities achieving a minimum of at least 3000 MET-minutes per week.
2. Moderate: a person not meeting the criteria for the "high" category but meeting any of the following criteria is classified in this category:
   - Three or more days of vigorous-intensity activity of at least 20 minutes per day or
   - Five or more days of moderate-intensity activity or walking of at least 30 minutes per day or
   - Five or more days of any combination of walking and moderate- or vigorous-intensity activities achieving a minimum of at least 600 MET-minutes per week.
3. Low: a person not meeting any of the above-mentioned criteria falls in this category.

2.3. Physical examination and anthropometric measurements

Weight and height of participants were determined in light clothing and without shoes. Portable calibrated electronic weighing scale and portable measuring inflexible bars were used. Waist circumference (WC) was measured using constant tension tape at the end of a normal expiration, with arms relaxed at the sides, at the midpoint between the lower part of the lowest rib and the highest point of the hip on the midaxillary line. The body mass index (BMI; in kilograms per square meter) was calculated according to the Quetelet formula. Blood pressure (BP) was measured with a calibrated Omron (Kyoto, Japan) M7 sphygmomanometer (HEM-780-E). The average of 3 measurements, made at intervals of 5 minutes, was used for analysis.

2.4. Biochemical measurements

The participants who consented to laboratory measurements were instructed to go on an overnight fasting for 10 to 12 hours before blood sampling. Blood samples were taken at sitting position according to the standard protocol, immediately centrifuged, and transferred under cold chain condition to the central reference laboratory of the Ministry of Health of Iran (Tehran, Iran). Fasting plasma glucose (FPG), triglycerides (TG), and high-density lipoprotein cholesterol (HDL-C) levels were determined. Fasting plasma glucose was measured by the enzymatic colorimetric method using glucose oxidize test. Serum TG and HDL-C were determined by enzymatic methods (Parsazmun, Karaj, Iran). Within-assay and between-assay coefficients of variation were, respectively, 1.82% and 1.60% for TG and 1.74% and 1.19% for FPG.

2.5. Definitions

We used the following definitions. *Metabolic syndrome* was defined according to the International Diabetes Federation (IDF; including our recently established cutoff for the Iranian population [7]) and the Adult Treatment Panel III (ATP III) [22] criteria. For establishing a diagnosis of MetS based on the IDF criteria (for use in Iran), one needs to demonstrate the presence of abdominal obesity (WC ≥91.5 cm in men and WC ≥85.5 cm in women) plus at least 2 of the following: raised TG (≥150 mg/dL), low levels of HDL (<40 mg/dL in men and <50 mg/dL in women), raised BP (systolic BP ≥130 mm Hg, diastolic BP ≥85 mm Hg, or treatment of previously diagnosed hypertension), and raised FPG (≥100 mg/dL) or previously diagnosed type 2 diabetes mellitus. Based on the ATP III criteria, 3 or more of the following are required to be present for the diagnosis of MetS: abdominal obesity (WC >102 cm in men and WC

Table 1
Characteristics of participants in low–, moderate–, and high–physical activity categories

	Low category	Moderate category	High category	*P*
n (%)	1317 (40.0)	813 (24.7)	1166 (35.4)	
Burden[a]	12.5	7.7	11.1	
Age (y)	44.48 ± 0.33	44.29 ± 0.42	43.37 ± 0.34	.054
Male (%)	523 (39.7)	391 (48.1)	753 (64.6)	<.001
Area of residence				<.001
Urban (%)	887 (67.4)	556 (68.4)	680 (58.3)	
Rural (%)	430 (32.6)	257 (31.6)	486 (41.7)	
BMI (kg/m^2)	27.18 ± 0.22	26.58 ± 0.23	25.86 ± 0.20	<.001
WC (cm)	90.33 ± 0.36	89.05 ± 0.41	87.39 ± 0.37	<.001
Smoking status				<.001
Never smoker (% ± SEM)	83.8 ± 1.7	83.3 ± 1.7	76.2 ± 1.7	
Ex-smoker (% ± SEM)	3.9 ± 0.5	4.6 ± 0.7	6.2 ± 0.8	
Current smoker (% ± SEM)	12.3 ± 1.5	12.1 ± 1.4	17.6 ± 1.5	
Occupation (% ± SEM)				<.001
Government employee	9.1 ± 1.1	15.2 ± 1.9	12.3 ± 1.7	
Nongovernment employee	4.3 ± 1.3	4.7 ± 1.0	7.5 ± 1.3	
Self-employed	20.7 ± 2.1	21.0 ± 2.3	39.9 ± 2.4	
Others[b]	65.9 ± 2.6	59.1 ± 2.8	40.3 ± 2.7	
Systolic BP (mm Hg)	124.53 ± 0.72	122.87 ± 0.82	120.77 ± 0.62	<.01
Diastolic BP (mm Hg)	81.01 ± 0.47	80.29 ± 0.53	79.89 ± 0.45	.116
TG (mg/dL)	155.41 ± 3.04	149.41 ± 3.04	140.67 ± 2.27	<.01
HDL-C (mg/dL)	34.81 ± 0.46	36.50 ± 0.40	38.29 ± 0.50	<.001
FPG (mg/dL)	96.49 ± 1.43	92.08 ± 1.17	89.55 ± 0.85	<.001
No Met (ATP III)	1.76 ± 0.06	1.65 ± 0.06	1.44 ± 0.05	<.001
No Met (IDF)[c]	2.08 ± 0.06	1.91 ± 0.06	1.70 ± 0.06	<.001
ATP III MetS (% ± SEM)	27.9 ± 2.0	25.8 ± 2.0	18.7 ± 1.5	<.001
Burden[a]	3.5	2.0	2.0	
IDF MetS (% ± SEM)[c]	33.2 ± 1.9	29.9 ± 2.1	24.0 ± 1.9	<.001
Burden[a]	4.1	2.3	2.7	

No Met (ATP III): number of metabolic abnormalities according to the ATP III criteria. No Met (IDF): number of metabolic abnormalities according to the IDF criteria. Variables are mean ± standard error or frequency (percentage). Variables are weighted for age, sex, and residential area of the population of Iran in 2006.

[a] Total national estimate using the data of the 2006 national census within complex survey analysis (numbers are rounded to the nearest million).

[b] Homemaker, nonpaid work, retired, student, soldier, or unemployed.

[c] Using waist cutoffs for Iran (WC ≥91.5 cm in men and WC ≥85.5 cm in women [5]).

Table 2
Crude associations between features of physical activity and ATP III–defined MetS and its components

	Obesity	High WC	High FPG	High BP	High TG	Low HDL-C	MetS
Male							
TPA (−240 MET-min/d change)	1.34*** (1.20-1.51)	1.46*** (1.32-1.62)	1.46*** (1.25-1.70)	1.07** (1.02-1.12)	1.10** (1.02-1.18)	1.33*** (1.20-1.46)	1.30*** (1.15-1.46)
Vigorous-intensity activity (−30 min/d change)	1.41*** (1.19-1.69)	1.57*** (1.35-1.83)	1.63*** (1.34-1.98)	1.11** (1.03-1.20)	1.15** (1.05-1.27)	1.43*** (1.23-1.66)	1.39*** (1.17-1.65)
Moderate-intensity activity (−60 min/d change)	1.28*** (1.13-1.44)	1.38*** (1.15-1.66)	1.30*** (1.11-1.53)	1.04 (0.94-1.15)	1.05* (1.01-1.10)	1.21*** (1.08-1.36)	1.22*** (1.09-1.37)
Sedentary behaviors (−2 h/d change)	0.68** (0.53-0.87)	0.69** (0.56-0.86)	0.55** (0.38-0.78)	0.61*** (0.49-0.76)	0.97 (0.75-1.25)	0.90 (0.70-1.16)	0.73** (0.58-0.92)
Female							
TPA (−240 MET-min/d change)	1.26*** (1.13-1.40)	1.40*** (1.28-1.54)	1.32** (1.10-1.58)	1.06** (1.01-1.10)	1.07** (1.02-1.13)	1.23*** (1.12-1.35)	1.22*** (1.10-1.36)
Vigorous-intensity activity (−30 min/d change)	1.33*** (1.16-1.52)	1.52*** (1.31-1.76)	1.54*** (1.28-1.85)	1.09** (1.03-1.14)	1.13** (1.04-1.23)	1.28*** (1.13-1.46)	1.31*** (1.12-1.54)
Moderate-intensity activity (−60 min/d change)	1.19*** (1.07-1.31)	1.33*** (1.12-1.58)	1.25** (1.09-1.44)	1.02 (0.89-1.17)	1.03 (0.96-1.11)	1.16** (1.05-1.29)	1.17** (1.05-1.30)
Sedentary behaviors (−2 h/d change)	0.70** (0.56-0.87)	0.70** (0.58-0.86)	0.46*** (0.34-0.63)	0.72** (0.58-0.89)	0.78* (0.62-0.99)	1.04 (0.82-1.31)	0.76** (0.62-0.93)

Obesity is defined as BMI of at least 30 kg/m^2. Data are presented as odds ratios (95% CIs) after being weighted for age, sex, and residential area of the population of Iran in 2006.
* *P* less than .05.
** *P* less than .01.
**** *P* less than .001.

>88 cm in women), raised TG (≥150 mg/dL), low HDL-C levels (<40 mg/dL in men and <50 mg/dL in women), raised BP (systolic BP ≥130 mm Hg, diastolic BP ≥85 mm Hg), and raised FPG (≥110 mg/dL).

2.6. Statistical analysis

Statistical analysis was performed in SPSS 16 for Windows (Chicago, IL). We carried out a complex sample survey analysis and, for extrapolation of the results to the Iranian adult population, weighted the data for sex, age (10-year strata), and residential area (urban/rural) according to the results of the national census of Iran in 2006 (n = 31 409 737; age, 25-64 years [23]). To compare the groups with different categories/intensities of physical activity for continuous variables, we used the method of general linear modeling in complex sample analysis mode using the F statistic. Adjustment for multiple comparisons was done using the least significant difference method. Comparisons for categorical variables were made by design-based χ^2 analysis. Multivariate logistic regression analysis was used to evaluate the independent association between features of physical activity and MetS (or the number of metabolic abnormalities) after adjustment for potential confounders. Continuous variables are expressed as mean ± standard error of the mean (SEM). *P* less than .05 was considered statistically significant.

3. Results

There were no significant differences between the excluded participants and the remaining subjects in age (38.7 ± 0.66 vs 39.4 ± 0.58 years, respectively; *P* = .136), sex (male/female: 454/483 vs 1667/1629, respectively; *P* = .267), and area of residence (urban/rural: 581/356 vs 2123/1173, respectively; *P* = .189). Table 1 shows the results of univariate analysis. Women and residents of urban areas tended to belong to lower categories of physical activity (*P* < .001). Smokers, nongovernment employees, and self-employed individuals tended to belong to higher categories of activity (*P* < .001). The BMI (*P* < .001), WC (*P* < .001), systolic BP (*P* < .01), TG (*P* < .01), FPG (*P* < .001), number of metabolic abnormalities (*P* < .001), and the prevalence of both IDF- and ATP III–defined MetS (*P* < .001) significantly decreased across categories with increasing physical activity. High-density lipoprotein cholesterol had the opposite trend (*P* < .001). Using our data, we estimated the national prevalence of MetS to be 29.1% (95% confidence interval [CI] = 26.5%-31.9%) with the IDF criteria (24.7% [95% CI = 21.3%-28.4%] in men and 33.7% [95% CI = 29.9%-37.7%] in women) and 24.2% (95% CI = 21.8%-26.8%) with the ATP III criteria (16.4% [95% CI = 13.8%-19.4%] in men and 32.2% [95% CI = 28.5%-36.1%] in women), corresponding to 9.1 and 7.6 million Iranian adults, respectively.

Tables 2 and 3 show detailed analysis of the association between various features of physical activity, MetS, and its

Table 3
Association of features of physical activity with ATP III–defined MetS and its components

		High WC	High FPG	High BP	High TG	Low HDL-C	MetS
TPA[a] (−240 MET-min/d change)							
Adjustment	Model A	1.36*** (1.27-1.46)	1.37*** (1.21-1.54)	1.06** (1.01-1.11)	1.08** (1.02-1.14)	1.24*** (1.17-1.32)	1.23*** (1.14-1.32)
	Model B	1.26*** (1.15-1.37)	1.35*** (1.20-1.53)	1.03 (0.98-1.09)	1.05 (0.99-1.12)	1.21*** (1.14-1.29)	1.14*** (1.06-1.23)
	Model C	1.26*** (1.16-1.38)	1.30*** (1.15-1.47)	1.02 (0.96-1.08)	1.04 (0.98-1.11)	1.21*** (1.14-1.29)	1.14*** (1.05-1.23)
Vigorous-intensity activity (−30 min/d change)							
Adjustment	Model A	1.47*** (1.32-1.63)	1.58*** (1.27-1.97)	1.09** (1.02-1.17)	1.13** (1.05-1.22)	1.33*** (1.22-1.45)	1.31*** (1.18-1.45)
	Model B	1.27*** (1.13-1.43)	1.55*** (1.24-1.93)	1.06 (0.98-1.14)	1.08* (1.00-1.17)	1.28*** (1.17-1.40)	1.30*** (1.17-1.44)
	Model D	1.25*** (1.11-1.41)	1.48*** (1.19-1. 83)	1.04 (0.97-1.12)	1.07 (0.99-1.16)	1.27*** (1.16-1.39)	1.28*** (1.15-1.42)
Moderate-intensity activity (−60 min/d change)							
Adjustment	Model A	1.30*** (1.17-1.44)	1.25** (1.06-1.48)	1.01 (0.93-1.11)	1.01 (0.92-1.11)	1.16** (1.06-1.28)	1.16** (1.05-1.30)
	Model B	1.28*** (1.12-1.45)	1.26** (1.07-1.47)	1.00 (0.91-1.10)	1.01 (0.92-1.11)	1.15** (1.04-1.26)	1.15* (1.03-1.28)
	Model E	1.28*** (1.12-1.46)	1.20* (1.02-1.41)	0.98 (0.89-1.08)	1.00 (0. 91-1.10)	1.14** (1.04-1.26)	1.12* (1.01-1.25)
Sedentary behaviors (−2 h/d change)							
Adjustment	Model A	0.83* (0.71-0.98)	0.53*** (0.43-0.65)	0.66*** (0.56-0.77)	0.88 (0.75-1.04)	1.01 (0.86-1.18)	0.84* (0.70-0.99)
	Model B	0.96 (0.78-1.18)	0.55*** (0.44-0.68)	0.68*** (0.58-0.80)	0.93 (0.79-1.10)	1.06 (0.90-1.25)	0.93 (0.77-1.12)
	Model F	1.01 (0.82-1.25)	0.57*** (0.47-0.73)	0.68*** (0.58-0.80)	0.94 (0.79-1.10)	1.13 (0.96-1.13)	0.94 (0.78-1.15)

Model A: adjustment for age, sex, and area of residence. Model B: adjustment for age, sex, area of residence, BMI, and smoking. Model C: adjustment for B and duration of sedentary behaviors. Model D: adjustment for B, duration of moderate-intensity activity, and sedentary behaviors. Model E: adjustment for B, duration of vigorous-intensity activity, and sedentary behaviors. Model F: adjustment for B and TPA. Multiple logistic regression analysis was used for adjustments in each model. The dependent variable (coded 0 or 1) was high WC, high FPG, high BP, high TG, low HDL-C, or MetS. The independent variables were age group, sex, area of residence, BMI, smoking, duration of sedentary behaviors, duration of moderate-intensity activity, duration of vigorous-intensity activity, and TPA, depending on the model. Data are presented as odds ratios (95% CIs).

[a] 240 MET-min/d TPA is equivalent to 30 min/d vigorous activity or 60 min/d moderate activity.

* *P* less than .05.

** *P* less than .01.

*** *P* less than .001.

components. Reduced TPA and vigorous-intensity activity were significantly associated with MetS and all of its components in both sexes ($P < .01$). The duration of sedentary behaviors was significantly associated with MetS and its components (except low HDL-C in both sexes and high TG in men) ($P < .05$). Among MetS components,

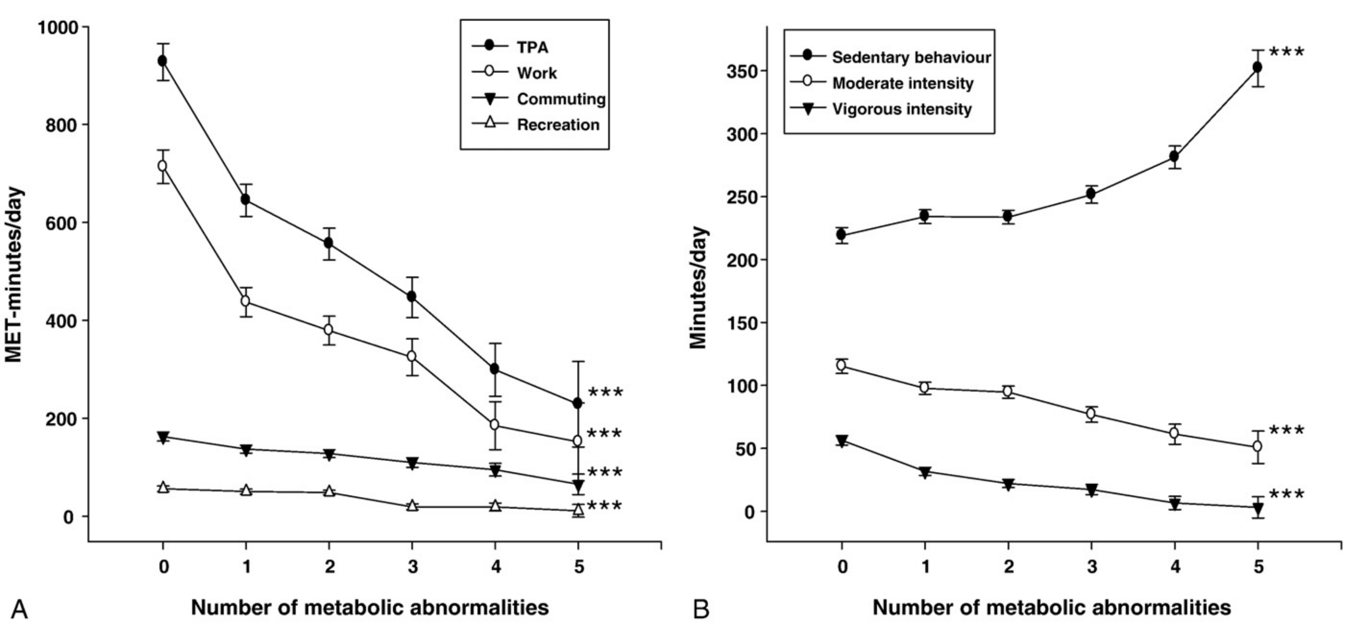

Fig. 1. After adjustment for age, sex, and residential area, there was a significant ($P < .001$) correlation between the number of metabolic abnormalities (ATP III defined) and the following variables: TPA, activity at work, activity at commuting, and activity at recreation (A). There was a significant association ($P < .001$) between the number of metabolic abnormalities and the following variables: duration of sedentary behaviors, moderate-intensity activity, and vigorous-intensity activity after adjustment for age, sex, and residential area (B). Data are expressed as mean (SEM). ***P less than .001.

central obesity and dysglycemia had the strongest association with low physical activity, whereas the weakest associations were for high BP and high TG. Reduced vigorous-intensity activity was the strongest predictor of MetS. Independent of other variables, the risk for MetS increased 1.28-fold with every 30-min/d reduction in vigorous-intensity activity (95% CI = 1.15-1.42, $P < .001$). The figure was 1.14-fold (95% CI = 1.05-1.23, $P < .001$) for every 240–MET-min/d decrease in TPA and 1.12-fold (95% CI = 1.01-1.25, $P < .05$) for every 60-min/d decrease in moderate-intensity activity. The same patterns as with the ATP III criteria were observed when using the modified cutoffs for Iran within the IDF criteria. Independent of age, sex, and residential area, the risk for IDF-defined MetS increased 1.20-fold (95% CI = 1.11-1.30, $P < .001$), 1.29-fold (95% CI = 1.17-1.42, $P < .001$), and 1.13-fold (95% CI = 1.04-1.22, $P < .01$) with every 240–MET-min/d, 30-min/d, and 60-min/d reduction in TPA, vigorous-intensity activity, and moderate-intensity activity, respectively.

Total physical activity and MET-minutes of activity at work, commuting, and recreation significantly decreased with increasing numbers of metabolic abnormalities ($P < .001$). The same trend was seen for the duration of vigorous- or moderate-intensity physical activity ($P < .001$), whereas the duration of sedentary behaviors significantly ($P < .01$) increased with increasing numbers of metabolic abnormalities (Fig. 1). Fig. 2 depicts the prevalence of ATP III–defined MetS and its components in physical activity categories. Age-, sex-, and residential area–weighted prevalence of ATP III–defined MetS and all its components significantly increased with decreasing categories/intensities of physical activity ($P < .01$).

4. Discussion

In this study, the duration and intensity (vigorous vs moderate) of physical activity in the 3 domains of work, commuting, and recreation were assessed using the GPAQ questionnaire. To estimate physical activity energy expenditure, MET-minutes of activities in different domains were calculated and summed up to yield TPA. Female sex was associated with lower categories of physical activity. This observation can be explained by sociocultural factors that cause Iranian females to be less actively involved in outdoor works. Urbanization was another correlate of lower-activity categories. Expectedly, nongovernment employees and self-employed individuals tended to be in higher-activity categories. After adjustments for age, sex, residential area, smoking, and BMI, we demonstrated a significant association between TPA and MetS. Furthermore, both moderate- and vigorous-intensity activities were independently correlated with lower prevalence of MetS. The duration of sedentary behaviors was independently associated with MetS. We demonstrated, after adjustment for age, sex, and residential area, a significant association between the number of metabolic abnormalities and lower levels of various aspects of physical activity.

We estimated the prevalence of MetS to be 29.1% among Iranian adults. This estimate is in agreement with the results

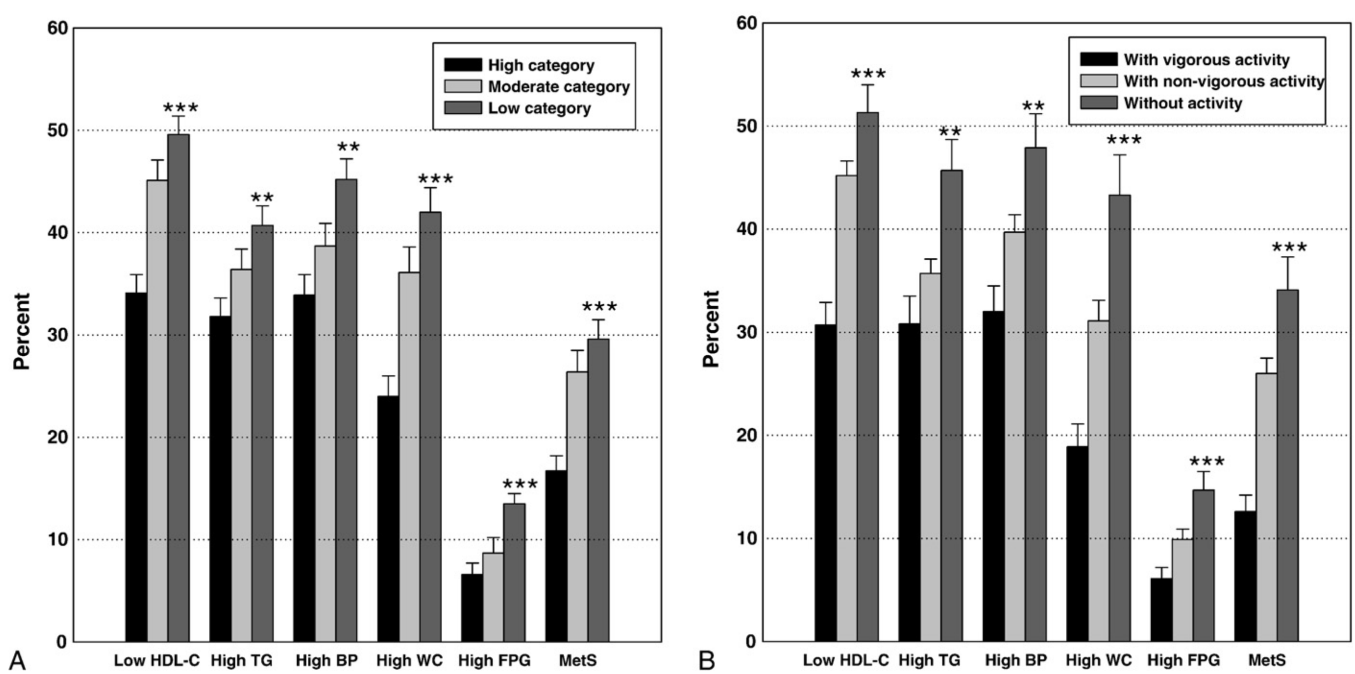

Fig. 2. Prevalence of ATP III–defined MetS and its components significantly increased from high to moderate to low categories of physical activity (A). Less active participants had significantly higher percentage of MetS and its components (B). Data are expressed as mean (SEM) after being weighted for age, sex, and residential area according to the population of Iran in 2006. **P less than .01, ***P less than .001.

of our recent study in Tehran, in which an estimate of approximately 27% was made for MetS prevalence [7]. Progressive urbanization is an important factor underlying the high prevalence of MetS and its correlates in Iran. In a large study (age, 15-64 years) in the northeast of Iran, urbanization was significantly correlated to the increasing prevalence of type 2 diabetes mellitus [24]. Similarly, the prevalence of diabetes was linked to urbanization in a recent study (age >19 years) in central Iran [25]. Nutritionally related health patterns have changed dramatically in the Middle East during recent years, partly because of social development in the absence of steady economic growth. Changes in dietary and physical activity patterns as well as inequality in health care are other important factors [26].

Despite differences in study design, sampling protocol, questionnaires, MetS definition, method of analysis, and age of participants, our results are conceptually in line with studies that documented the association between MetS and exercise [9,27,28], total activity (using METs) [29], duration of vigorous- or moderate-intensity activity [29,30], physical activity categories (using study-specific definitions) [2,12,30-36], leisure time activity [11,36-40], and watching TV as a representative of sedentary behaviors [11,30,35,40-42]. The present study is distinct from many others in that (1) our sample represents Iran's population, (2) all domains of physical activity (work, commuting, and recreation) and the time spent in each of them were evaluated, and (3) associations were adjusted for potential confounders. To have a more accurate estimate of total activity, work-time activity was taken into account. In addition, we considered all features of sedentary behaviors such as sitting at a desk, traveling on bus or train, reading, watching television, or working with computer.

Using an international questionnaire, which would facilitate comparison of our results with future studies, we showed that by each 240–MET-minute increase in daily TPA, MetS prevalence is reduced approximately 20%. These results are of extreme importance for a developing country like Iran whose population is experiencing an increasingly sedentary life and is thus exposed to higher risks of MetS. Interestingly, the duration of vigorous activity had a somewhat more prominent effect than the duration of moderate activity on MetS prevalence. Although the contribution of a 60-min/d increase in moderate activity to TPA is equal to that of a 30-min/d increase in vigorous activity, they were associated with different rates of reduction in MetS prevalence (16% and 31%, respectively), highlighting the importance of vigorous-intensity activity.

We explored the association between physical activity and individual components of MetS separately. Higher levels of TPA were associated with a significant decrease in the prevalence of central obesity, dyslipidemia, dysglycemia, and high BP. However, BMI significantly confounded the association of TPA with high BP and hypertriglyceridemia. Previous reports have led to inconsistent findings about the association between physical activity and some MetS components. Some studies have demonstrated a significant association for BP [30,31,43-45], whereas others have failed to do so [11,29,34,35]. The situation is the same for dyslipidemia and dysglycemia [11,30,31,34,35,43-45]. However, all of these studies reported associations between physical activity and more than 1 MetS component. This suggests that the beneficial effects of physical activity may be exerted either simultaneously on several risk factors or on their common underlying mechanism (eg, insulin resistance). Various aspects of physical activity declined significantly with increasing numbers of metabolic abnormalities in our series.

There are a few studies carried out in the Middle East that examined the relationship between physical activity and MetS. A recent study in Turkey showed that ATP III–defined MetS was negatively associated with levels of physical activity [46]. Similarly, the prevalence of ATP III–defined MetS in subjects with a sedentary lifestyle was significantly higher than that in active subjects of both sexes in a study in 3 central cities of Iran [47]. The present study is a nationally representative report from Iran elucidating the association of physical activity and MetS and is one of the largest studies on the subject. The questionnaire (approved by the World Health Organization) we used can serve as a standard questionnaire to make community-level physical activity assessments more feasible. It should be pointed out, however, that certain factors such as recall bias might have negatively influenced the accuracy of physical activity data collected by questionnaires. Furthermore, as our study was cross-sectional, it cannot prove potential causal relationships. Longitudinal data are required to assess whether low levels of moderate and vigorous activity do increase the risk of MetS.

In conclusion, our study indicated a significant relationship between MetS and various aspects of physical activity. Longer durations of moderate- and vigorous-intensity activity were associated with reduced odds of MetS. Clustering of MetS components was seen in persons with higher levels of sedentary behaviors. The MetS components are risk factors for cardiovascular diseases as well. Therefore, any strategy that reduces the prevalence of MetS may lead to a reduction in the prevalence of cardiovascular diseases. In Iran, like other countries, MetS has an independent association with ischemic heart disease [48]. Our findings suggest that, to reduce the prevalence of the MetS and its consequences, increased participation in physical activity should be encouraged. Women and urban residents need to be the focus of more intensive attention. In the absence of contraindications, more vigorous-intensity activity should also be considered to obtain additional health benefits.

Acknowledgment

This study was supported by the Ministry of Health and Medical Education, Tehran, Iran.

References

[1] Reaven GM. Insulin resistance, the insulin resistance syndrome, and cardiovascular disease. Panminerva Med 2005;47:201-10.

[2] Park YW, Zhu S, Palaniappan L, Heshka S, Carnethon MR, Heymsfield SB. The metabolic syndrome: prevalence and associated risk factor findings in the US population from the Third National Health and Nutrition Examination Survey, 1988-1994. Arch Intern Med 2003;163:427-36.

[3] Wildman RP, Muntner P, Reynolds K, et al. The obese without cardiometabolic risk factor clustering and the normal weight with cardiometabolic risk factor clustering: prevalence and correlates of 2 phenotypes among the US population (NHANES 1999-2004). Arch Intern Med 2008;168:1617-24.

[4] Gu D, Reynolds K, Wu X, et al. Prevalence of the metabolic syndrome and overweight among adults in China. Lancet 2005;365:1398-405.

[5] Eckel RH, Grundy SM, Zimmet PZ. The metabolic syndrome. Lancet 2005;365:1415-28.

[6] Ghassemi H, Harrison G, Mohammad K. An accelerated nutrition transition in Iran. Public Health Nutr 2002;5:149-55.

[7] Esteghamati A, Ashraf H, Rashidi A, Meysamie A. Waist circumference cut-off points for the diagnosis of metabolic syndrome in Iranian adults. Diabetes Res Clin Pract 2008;82:104-7.

[8] Cameron AJ, Shaw JE, Zimmet PZ. The metabolic syndrome: prevalence in worldwide populations. Endocrinol Metab Clin North Am 2004;33:351-75.

[9] Carroll S, Dudfield M. What is the relationship between exercise and metabolic abnormalities? A review of the metabolic syndrome. Sports Med 2004;34:371-418.

[10] Lakka TA, Laaksonen DE. Physical activity in prevention and treatment of the metabolic syndrome. Appl Physiol Nutr Metab 2007;32:76-88.

[11] Bertrais S, Beyeme-Ondoua JP, Czernichow S, Galan P, Hercberg S, Oppert JM. Sedentary behaviors, physical activity, and metabolic syndrome in middle-aged French subjects. Obes Res 2005;13:936-44.

[12] Brien SE, Katzmarzyk PT. Physical activity and the metabolic syndrome in Canada. Appl Physiol Nutr Metab 2006;31:40-7.

[13] Chen X, Pang Z, Li K. Dietary fat, sedentary behaviors and the prevalence of the metabolic syndrome among Qingdao adults. Nutr Metab Cardiovasc Dis 2009;19:27-34.

[14] Vella CA, Zubia RY, Ontiveros D, Cruz ML. Physical activity, cardiorespiratory fitness, and metabolic syndrome in young Mexican and Mexican-American women. Appl Physiol Nutr Metab 2009;34:10-7.

[15] Hahn V, Halle M, Schmidt-Trucksass A, Rathmann W, Meisinger C, Mielck A. Physical activity and the metabolic syndrome in elderly German men and women: results from the population-based KORA survey. Diabetes Care 2009;32:511-3.

[16] Yang X, Telama R, Hirvensalo M, Mattsson N, Viikari JS, Raitakari OT. The longitudinal effects of physical activity history on metabolic syndrome. Med Sci Sports Exerc 2008;40:1424-31.

[17] Karelis AD, Lavoie ME, Messier V, et al. Relationship between the metabolic syndrome and physical activity energy expenditure: a MONET study. Appl Physiol Nutr Metab 2008;33:309-14.

[18] Ford ES, Li C. Physical activity or fitness and the metabolic syndrome. Expert Rev Cardiovasc Ther 2006;4:897-915.

[19] CDC of Iran. The profile of the third national surveillance of non-communicable disease risk factors in the I.R. of Iran. Tehran, Iran. Center for Disease Control, Ministry of Health & Medical Education; 2008.

[20] WHO. Global Physical Activity Questionnaire (GPAQ). Geneva (Switzerland), World Health Organization. Available from: www.who.int/entity/chp/steps/resources/GPAQ_Analysis_Guide.pdf. Accessed October 1, 2008.

[21] IPAQ. International Physical Activity Questionnaire. Available from: http://www.ipaq.ki.se. Accessed March 1, 2008.

[22] Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults. Executive summary of the third report of the National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III). JAMA 2001;285:2486-97.

[23] Statistical Center of Iran. Population estimates. Available from: http://www.sci.org.ir/portal/faces/public/sci/sci.gozide/sci.PopEstimate. Accessed October 1, 2008.

[24] Azimi-Nezhad M, Ghayour-Mobarhan M, Parizadeh MR, et al. Prevalence of type 2 diabetes mellitus in Iran and its relationship with gender, urbanisation, education, marital status and occupation. Singapore Med J 2008;49:571-6.

[25] Sadeghi M, Roohafza H, Shirani S, et al. Diabetes and associated cardiovascular risk factors in Iran: the Isfahan Healthy Heart Programme. Ann Acad Med Singapore 2007;36:175-80.

[26] Galal O. Nutrition-related health patterns in the Middle East. Asia Pac J Clin Nutr 2003;12:337-43.

[27] Mitsui T, Shimaoka K, Tsuzuku S, Kajioka T, Sakakibara H. Gentle exercise of 40 minutes with dietary counseling is effective in treating metabolic syndrome. Tohoku J Exp Med 2008;215:355-61.

[28] Katzmarzyk PT, Leon AS, Wilmore JH, et al. Targeting the metabolic syndrome with exercise: evidence from the HERITAGE Family Study. Med Sci Sports Exerc 2003;35:1703-9.

[29] Rennie KL, McCarthy N, Yazdgerdi S, Marmot M, Brunner E. Association of the metabolic syndrome with both vigorous and moderate physical activity. Int J Epidemiol 2003;32:600-6.

[30] Dunstan DW, Salmon J, Owen N, et al. Associations of TV viewing and physical activity with the metabolic syndrome in Australian adults. Diabetologia 2005;48:2254-61.

[31] Pitsavos C, Panagiotakos DB, Chrysohoou C, Kavouras S, Stefanadis C. The associations between physical activity, inflammation, and coagulation markers, in people with metabolic syndrome: the ATTICA study. Eur J Cardiovasc Prev Rehabil 2005;12:151-8.

[32] Martinez MA, Puig JG, Mora M, et al. Metabolic syndrome: prevalence, associated factors, and C-reactive protein: the MADRIC (MADrid RIesgo Cardiovascular) Study. Metabolism 2008;57:1232-40.

[33] Ma G, Luan D, Li Y, et al. Physical activity level and its association with metabolic syndrome among an employed population in China. Obes Rev 2008;9(Suppl 1):113-8.

[34] Bianchi G, Rossi V, Muscari A, Magalotti D, Zoli M. Physical activity is negatively associated with the metabolic syndrome in the elderly. QJM 2008;101:713-21.

[35] Li CL, Lin JD, Lee SJ, Tseng RF. Associations between the metabolic syndrome and its components, watching television and physical activity. Public Health 2007;121:83-91.

[36] Halldin M, Rosell M, de Faire U, Hellenius ML. The metabolic syndrome: prevalence and association to leisure-time and work-related physical activity in 60-year-old men and women. Nutr Metab Cardiovasc Dis 2007;17:349-57.

[37] Holme I, Tonstad S, Sogaard AJ, Larsen PG, Haheim LL. Leisure time physical activity in middle age predicts the metabolic syndrome in old age: results of a 28-year follow-up of men in the Oslo study. BMC Public Health 2007;7:154.

[38] Wilsgaard T, Jacobsen BK. Lifestyle factors and incident metabolic syndrome. The Tromso Study 1979-2001. Diabetes Res Clin Pract 2007;78:217-24.

[39] Laaksonen DE, Lakka HM, Salonen JT, Niskanen LK, Rauramaa R, Lakka TA. Low levels of leisure-time physical activity and cardiorespiratory fitness predict development of the metabolic syndrome. Diabetes Care 2002;25:1612-8.

[40] Wijndaele K, Duvigneaud N, Matton L, et al. Sedentary behaviour, physical activity and a continuous metabolic syndrome risk score in adults. Eur J Clin Nutr 2009;63:421-9.

[41] Chang PC, Li TC, Wu MT, et al. Association between television viewing and the risk of metabolic syndrome in a community-based population. BMC Public Health 2008;8:193.

[42] Gao X, Nelson ME, Tucker KL. Television viewing is associated with prevalence of metabolic syndrome in Hispanic elders. Diabetes Care 2007;30:694-700.
[43] Mohan V, Gokulakrishnan K, Deepa R, Shanthirani CS, Datta M. Association of physical inactivity with components of metabolic syndrome and coronary artery disease—the Chennai Urban Population Study (CUPS no. 15). Diabet Med 2005;22: 1206-11.
[44] Ekelund U, Brage S, Franks PW, Hennings S, Emms S, Wareham NJ. Physical activity energy expenditure predicts progression toward the metabolic syndrome independently of aerobic fitness in middle-aged healthy Caucasians: the Medical Research Council Ely Study. Diabetes Care 2005;28:1195-200.
[45] Simmons RK, Griffin SJ, Steele R, Wareham NJ, Ekelund U. Increasing overall physical activity and aerobic fitness is associated with improvements in metabolic risk: cohort analysis of the ProActive trial. Diabetologia 2008;51:787-94.
[46] Erem C, Hacihasanoglu A, Deger O, et al. Prevalence of metabolic syndrome and associated risk factors among Turkish adults: Trabzon MetS study. Endocrine 2008;33:9-20.
[47] Sarrafzadegan N, Kelishadi R, Baghaei A, et al. Metabolic syndrome: an emerging public health problem in Iranian Women: Isfahan Healthy Heart Program. Int J Cardiol 2008;131:90-6.
[48] Nabipour I, Amiri M, Imami SR, et al. The metabolic syndrome and nonfatal ischemic heart disease; a population-based study. Int J Cardiol 2007;118:48-53.