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Physical activity patterns and metabolic syndrome in Costa Rica

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ABSTRACT

Objective. To examine whether total physical activity or activity patterns are associated with metabolic syndrome and its components.

Methods. Participants include 1994 controls from a case–control study of non-fatal myocardial infarction in Costa Rica (1994–2004). Physical activity was assessed via self-administered questionnaire and patterns were identified using principal components analysis. Metabolic syndrome was assessed via blood samples and anthropometry measurements from in-home study visits. Prevalence ratios (PRs) and 95% confidence intervals (CIs) were calculated using log binomial regression. Adjusted least squares means of metabolic syndrome components were calculated by quintile of total activity and pattern scores.

Results. Four activity patterns were identified: rest/sleep, agricultural, light indoor activity, and manual labor. Total activity was not associated with metabolic syndrome. Metabolic syndrome prevalence was 20% lower in participants with the highest scores on the agricultural job pattern compared to those with the lowest (PR: 0.80, 95% CI: 0.68–0.94). Higher total activity was associated with lower triglycerides and lower HDL cholesterol. Higher scores on each pattern were inversely associated with metabolic syndrome components, particularly waist circumference and fasting blood glucose.

Conclusions. Patterns or types of physical activity may be more strongly associated with metabolic syndrome and its components than total activity levels.

Introduction

Metabolic syndrome is characterized by several related cardiometabolic risk factors including abdominal obesity, hypertriglyceridemia, hypertension, low high-density lipoprotein (HDL) cholesterol, and elevated fasting glucose, and is significant because of its association with increased risk of diabetes and cardiovascular disease (Eckel et al., 2005; Expert Panel on Detection and Treatment of High Blood Cholesterol in Adults, 2001; Lakka et al., 2002). Prevalence of metabolic syndrome has increased in recent decades, in parallel with increases in obesity and diabetes, and is well over 20% in some countries (Ford et al., 2004; Halldin et al., 2007).

Preventing and reversing metabolic syndrome is a promising strategy for reducing its obesity-related comorbidities, and evidence suggests that physical activity is effective in preventing and treating metabolic syndrome (Ford and Li, 2006). Studies in several international populations suggest that higher total levels of physical activity are associated with lower incidence and prevalence of metabolic syndrome (Bertrais et al., 2005; Cho et al., 2009; Dunstan et al., 2005; He et al., 2013; Irwin et al., 2002; Lakka and Laaksonen, 2007; Panagiotakos et al., 2004; Santos et al., 2007; Zhu et al., 2004) and that low levels of physical activity are associated with progression to metabolic syndrome over time (Ekelund et al., 2005); however, these relationships may not be consistent by type or intensity of physical activity (Ford et al., 2005; He et al., 2013; Lakka and Laaksonen, 2007; Lakka et al., 2003). Cardiorespiratory fitness is also related to lower incidence (Ninomiya et al., 2004) and prevalence of metabolic syndrome (Irwin et al., 2002; Lakka and Laaksonen, 2007; Lee et al., 2005). Differences have been reported by type of physical activity, with some previous research suggesting that higher levels of leisure-time, but not occupational, physical activity are associated with lower metabolic syndrome prevalence (Halldin et al., 2007; Sisson et al., 2009). Relationships have also been reported between higher levels of leisure-time sedentary behavior and higher metabolic syndrome prevalence (Cho et al., 2009; Ford et al., 2005; Hamilton et al., 2007; Sisson et al., 2009).

The purpose of this study is to determine whether patterns of physical activity, identified through principal components analysis, are associated with metabolic syndrome or its components in a population-representative sample of Costa Rican adults with no history of myocardial

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infarction (MI). Given previous findings that associations between physical activity and metabolic syndrome may differ by type and intensity, examining activity patterns rather than total amounts may help capture associations not evident when looking at total activity. It is particularly important to address these questions in a population in the developing world, where prevalence of obesity and its comorbidities, including diabetes, has increased rapidly in recent decades (Malik et al., 2013).

Materials and methods

Study population

Participants were taken from the controls in a case–control study of non-fatal myocardial infarction (MI) conducted in the Central Valley of Costa Rica from 1994 to 2004. This study has been described previously (Baylin et al., 2003; Campos and Siles, 2000). Eligible cases were diagnosed with a first MI at one of the three hospitals in the study catchment area. Controls were matched to cases by age (within 5 years), sex, and county of residence using data from the National Census and Statistics Bureau of Costa Rica, and are representative of the general population within matching strata. The response rate for controls was 88%. Individuals were ineligible if they previously suffered an MI or were physically or mentally unable to answer the questionnaire.

The study enrolled a total of 2273 cases and 2274 controls. The analyses presented here are limited to controls. Additionally, participants were excluded if they were missing data on time spent sleeping ($n = 4$), reported sleeping less than 2 h per night ($n = 2$), were missing >2 physical activity questions ($n = 9$) or had insufficient physical activity data to conduct principal components analysis ($n = 32$), reported 6 + average METs/h of activity while awake ($n = 19$), >20 h/day of physical activity ($n = 185$), or total METs 2 + standard deviations from the mean (below 3.19 or above 67.86 METs/day) ($n = 97$); or whose metabolic syndrome status was unknown ($n = 29$). Exclusions were not mutually exclusive and yielded a final study population of 1994, including 916 participants with metabolic syndrome and 1078 without.

All participants gave informed consent. This study was approved by the Ethics Committee of the Harvard School of Public Health and the National Institute of Health Research (INISA) at the University of Costa Rica.

Data collection

Data collection was completed in participants' homes and included the administration of a detailed questionnaire; anthropomorphic measurements; and a blood sample. The questionnaire included information on sociodemographic characteristics; detailed medical history, including individual and family history of diabetes and hypertension; medication use; and health behaviors including smoking, diet, and physical activity.

Physical activity

Physical activity and energy expenditure were assessed using questions about sleep duration on weekends and weekdays and frequency and duration of several occupational, household, and leisure time activities during the previous year. This questionnaire was validated against its ability to predict performance on the Harvard Step test in previous studies in Puriscal, Costa Rica (Campos et al., 1991, 1992). Activities were assigned metabolic equivalent (MET) values based on their intensity. METs provide a standardized measure of estimated energy expenditure of several activities relative to a resting metabolic rate of 1.0 ((4.184 kJ)$\cdot$kg$^{-1}\cdot$h^{-1}), equivalent to sitting quietly, and were assigned to activities as follows: sleeping; napping; lying in bed during the day to read; watch television or listen to music (0.9 METs); sitting at work or in activities such as driving or watching TV (1.0 METs); standing in light activities at work (e.g. copying, filing) or at home (e.g. laundry, cooking, cleaning) (2.3 METs); standing doing general cleaning (e.g. mopping, sweeping, washing the car) or walking on flat terrain (2.5 METs); standing and kneeling doing yard work (3.0 METs); non-vigorous agriculture work or work in construction (4.5 METs); practicing sports (general) (6.0 METs); walking on mountainous terrain (6.3 METs); moving or carrying heavy items (e.g. furniture, luggage) (7.0 METs); practicing team sports (e.g. soccer, basketball) aerobics, racquet sports (7.2 METs); climbing stairs; practicing individual sports (e.g. swimming, running, cycling) (8.0 METs); and performing heavy or vigorous jobs (e.g. shoveling digging ditches, cutting trees) (8.5 METs) (Ainsworth et al., 1993, 2000).

Metabolic syndrome

Metabolic syndrome was defined based on the guidelines of the National Cholesterol Education Program's Adult Treatment Panel III (Expert Panel on Detection and Treatment of High Blood Cholesterol in Adults, 2001), and updated by the American Heart Association and National Heart, Lung, and Blood Institute (Grundy et al., 2005). Participants were classified as having metabolic syndrome if they had at least three of the following risk factors: waist circumference >102 cm in men or >88 cm in women; triglycerides ≥150 mg/dL or taking medication to lower triglycerides; high-density lipoprotein (HDL) cholesterol <40 mg/dL in men or <50 mg/dL in women, or taking medication to improve HDL cholesterol; systolic blood pressure ≥130 mm Hg or diastolic blood pressure ≥85 mm Hg or taking antihypertensive medication; or fasting glucose ≥100 mg/dL or taking medication to lower blood glucose. Waist circumference and blood pressure were each measured twice by study staff, and the average of the two measures was used in analysis. Triglycerides, HDL cholesterol, and fasting blood glucose were assessed using a fasting blood sample, and both the blood sample and blood pressure measurements were taken in the morning, after participants voided urine and rested for 10 min.

Data analysis

Physical activity patterns were identified using principal components analysis (PCA) on 18 physical activity variables using orthogonal varimax rotation to yield four components (physical activity patterns) that were independent and interpretable. The number of retained patterns was determined by examination of the scree plots, eigenvalues, the interpretability of the resulting patterns, and parsimony (Mertler and Vannatta, 2010). Participants' scores on each of the four components were calculated by summing the time spent in each activity, weighted by their component loadings. Higher component loadings indicate higher adherence to that pattern. The factor score for the light indoor activity pattern was reversed so that higher scores indicate higher levels of standing in light activities and doing general cleaning, and lower levels of sitting at work or in activities such as driving or watching television. Similar physical activity patterns emerged in a sensitivity analysis where PCA was conducted separately in men and women, so they are combined in the analyses presented here.

We used t-tests and chi-square tests to compare means and proportions between participants with and without metabolic syndrome. We used binomial models to estimate prevalence ratios and 95% confidence intervals of metabolic syndrome by quintiles of total physical activity and each physical activity pattern score. *P*-values for trend were obtained from the Wald test of quintiles of physical activity modeled as a continuous variable. Least squares means and 95% confidence intervals were estimated for each component of metabolic syndrome by quintile of total physical activity and quintile of each physical activity pattern score using generalized linear models. Linear mixed models with empirical variances were used in models of triglycerides and blood glucose, which were not normally distributed (Kim et al., 2010; White, 1980). Adjusted models included continuous age, sex, urbanicity (urban/periurban/rural), monthly household income (continuous), whether participants were current smokers (yes/no), and maternal or paternal history of hypertension (yes/no) and diabetes (yes/no). Inclusion of several additional dietary and other factors, including waist-to-hip ratio; total energy intake; percent of calories from protein, carbohydrate and total, monounsaturated, polyunsaturated, saturated and trans fat; total fiber intake; and total METs of physical activity did not affect the results and these variables are not included in the final models, unless otherwise noted.

All analyses were conducted using SAS 9.2 (SAS Institute, Cary, NC).

Results

Nearly half of the participants (45.9%) had metabolic syndrome. Participants with metabolic syndrome were older on average, a higher proportion was female, and a lower proportion lived in urban areas or was current smokers compared to those without metabolic syndrome (Table 1). Monthly household income was somewhat lower in participants with metabolic syndrome than in other respondents.

High blood pressure, hypertriglyceridemia, and low HDL cholesterol were the most prevalent components of metabolic syndrome among both participants with metabolic syndrome (91.7%, 90.5%, and 85.4%, respectively), and those without (47.6%, 52.2%, and 45.6%, respectively).

Table 1
Basic characteristics of study participants by metabolic syndrome status among controls, case–control study of acute myocardial infarction, Costa Rica, 1994–2004.

	Metabolic syndrome		P
	Yes (n = 916)	No (n = 1078)	
Demographic and health factors			
Age (years)	61.0	56.0	<0.001
Female (%)	38.5	18.9	<0.001
Reside in urban area (%)	38.4	42.7	0.054
Income (US$/month)	563	601	0.080
Current smokers (%)	14.9	25.3	<0.001
Components of metabolic syndrome (%)			
Abdominal obesity (waist circumference >102 cm for men; >88 cm for women)	45.6	3.5	<0.001
Hypertriglyceridemia (≥150 mg/dL)	90.5	52.2	<0.001
Low HDL cholesterol (<40 mg/dL for men; <50 for women)	85.4	45.6	<0.001
High blood pressure (≥130 mm Hg systolic and/or ≥85 mm Hg diastolic)	91.7	47.6	<0.001
High fasting blood glucose (≥100 mg/dL)	31.8	3.5	<0.001
Physical activity (METs/day)			
All physical activities	31.7	33.1	0.002
Sitting	5.0	4.8	0.22
Lying down/napping	2.0	1.6	<0.001
Light indoor activities	11.9	11.1	0.026
Light-to-moderate activities	4.0	5.3	<0.001
Vigorous activities	1.4	2.5	<0.001
Sports	1.0	1.2	0.12
Sleeping	6.4	6.4	0.72

HDL = high density lipoprotein.

Less than half of participants with metabolic syndrome were classified as having abdominal obesity (45.6%) or high fasting blood glucose (31.8%), and very few participants had either abdominal obesity (3.5%) or high fasting blood glucose (3.5%) without also having metabolic syndrome.

Total activity-related energy expenditure was lower in participants with metabolic syndrome (31.7 METs/day) compared to those without (33.1 METs/day). Participants with metabolic syndrome reported more METs per day of lying down or napping and of light indoor activities and fewer METs per day of light-to-moderate or vigorous activities than those without. METs per day from sitting, sleeping and playing sports did not differ by metabolic syndrome status.

Principal components analysis on the eighteen activities considered yielded four components describing broad activity patterns, as given in Table 2. Sleeping on weekdays and weekends loaded most heavily in the first component, which we describe as a *rest/sleep pattern*. The second component, including high factor loadings on working in agriculture, performing heavy and vigorous jobs, standing and kneeling doing yard work, and walking on mountainous terrain, is described as the *agriculture pattern*. The *light indoor activity pattern* scores were reversed for ease of interpretation, and higher scores indicate higher loadings on activities such as standing in light work activities such as copying or filing; and standing doing general cleaning, such as mopping or sweeping, and lower loadings on sitting in activities such as driving or watching TV.

Table 2
Component loadings for physical activity patterns from PCA, Costa Rica, 1994–2004.

	Components			
	1[a]	2[b]	3[c]	4[d]
Sleep during weekday	93[e]	0	7	10
Sleep during weekend	93[e]	−5	6	−6
Nap	−1	13	2	−35[e]
Lie in bed during the day to watch TV, read, listen to music	−41[e]	−8	17	−21
Sit, either at work or in activities such as driving or watching TV	5	−30[e]	77[e]	−12
Stand in very light activities at work (e.g. filing, copying) or at home (e.g. doing laundry or dishes)	−3	−36[e]	−65[e]	−5
Stand doing general cleaning (e.g. mopping, sweeping, washing windows)	7	0	−56[e]	−11
Stand or kneel doing yard work (e.g. weeding, pruning, watering)	6	51[e]	−2	1
Work in agriculture (not vigorously; e.g. picking coffee, cultivating, planting, fertilizing)	6	62[e]	9	−9
Work in construction (e.g. carpentry, roofing, painting, chopping wood)	4	14	11	62[e]
Walk on flat terrain	−8	29	−9	−3
Perform heavy and vigorous jobs (e.g. shoveling, cutting weeds, digging ditches, cutting trees)	6	55[e]	7	17
Walk on mountainous terrain	−3	47[e]	−2	−8
Climb stairs	1	−18	6	62[e]
Practice team sports (e.g. soccer, basketball, volleyball), aerobics or racquet sports	4	−10	10	28
Practice individual sports (e.g. running, cycling, swimming)	−3	−1	−1	14
Practice any other sports	−1	−12	2	21
Move or carry very heavy items (e.g. furniture, boxes, a person, water, luggage)	3	9	−6	31[e]

Note: Component loadings are multiplied ×100 and rounded to the nearest integer.
[a] Rest/sleep pattern.
[b] Agriculture pattern.
[c] Light indoor activity pattern.
[d] Manual labor pattern.
[e] Denotes scores with absolute values of at least 30.

Finally, the *manual labor pattern* included the highest factor loadings for working in construction and climbing stairs, and to a lesser extent, moving or carrying heavy items and a negative loading on lying down or napping.

Average total daily energy expenditure was 32.5 METs/day and ranged from 19.8 METs/day among participants in the lowest quintile of total energy expenditure to 47.8 METs/day among participants in the highest quintile of total energy expenditure (Table 3). Total energy expenditure varied from 30.5 METs/day among participants in the lowest quintile to 34.6 METs/day for participants in the highest quintile of scores for the rest/sleep pattern and from 33.4 to 40 METs/day for the agriculture pattern, 27.3 to 36.3 METs/day for light indoor activity, and 32.4 to 38 METs/day for the manual labor pattern.

Higher total daily energy expenditure was marginally associated with lower prevalence of metabolic syndrome in an unadjusted model, but this association attenuated after controlling for covariates. Prevalence of metabolic syndrome did not differ by scores for the rest/sleep pattern or light indoor activity pattern. Participants in the highest quintile of the agriculture pattern had 20% lower prevalence of metabolic syndrome than those with the lowest agriculture pattern scores after controlling for age, sex and urbanicity [prevalence ratio (PR): 0.80, 95% confidence interval (CI): 0.68, 0.94; $P_{trend} = 0.034$]. Further controlling for income, smoking status, family history of diabetes and hypertension, and total physical activity attenuated these results (PR for the highest vs. lowest quintile of agricultural job: 0.89, 95% CI: 0.77, 1.03). Higher scores on the manual labor pattern were associated with lower prevalence of metabolic syndrome when controlling for age, sex, and urbanicity, (PR for the highest vs. lowest quintile: 0.82, 95% CI: 0.70, 0.97; $P_{trend} = 0.006$). This association attenuated in the fully adjusted model, but the inverse association between manual labor pattern scores and metabolic syndrome remained marginally significant ($P_{trend} = 0.066$).

In fully-adjusted models, higher levels of total physical activity were associated with lower triglycerides ($P_{trend} = 0.047$), driven by low triglycerides among participants in the highest quintile of activity (208.9 mg/dL) compared with the lower quintiles (222.4–230.0 mg/dL) (Table 4). Similarly, higher total physical activity was marginally associated with lower diastolic blood pressure ($P_{trend} = 0.089$), driven by lower mean diastolic blood pressure in those in the highest quintile of METs per day (80.8 mm Hg) compared to those in the lower four quintiles (81.8–82.3 mm Hg). HDL cholesterol was highest (42.0 mg/dL) among participants in the lowest quintile of total activity compared with the highest (40.5 mg/dL). No clear association was evident between total physical activity and waist circumference, or fasting blood pressure.

Associations between physical activity and metabolic syndrome components were not consistent across physical activity patterns. Higher scores on the rest/sleep pattern were inversely associated with

Table 3
Prevalence ratios (PRs) and 95% confidence intervals (CIs) for metabolic syndrome by quintiles of total METs of physical activity overall and by scores on four physical activity patterns, Costa Rica, 1994–2004.

	Average METs/day	Model 1[a] PR (95% CI)	Model 2[b] PR (95% CI)	Model 3[c] PR (95% CI)	Model 4[d] PR (95% CI)
Total METs	32.5 (10.1)				
Q1	19.8 (3.3)	1.00 (ref)	1.00 (ref)	1.00 (ref)	–
Q2	26.7 (1.5)	1.05 (0.91, 1.21)	0.96 (0.85, 1.10)	1.03 (0.91, 1.17)	
Q3	31.7 (1.3)	0.97 (0.83, 1.12)	0.98 (0.85, 1.13)	0.95 (0.82, 1.09)	
Q4	36.4 (1.5)	1.04 (0.90, 1.20)	1.03 (0.90, 1.17)	1.05 (0.93, 1.18)	
Q5	47.8 (7.2)	0.86 (0.73, 1.01)	0.89 (0.76, 1.04)	0.96 (0.83, 1.10)	
P_{trend}[e]		0.085	0.46	0.67	
Factor 1: Rest/sleep					
Q1	30.5 (9.6)	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)
Q2	31.9 (10.0)	0.90 (0.77, 1.04)	0.96 (0.84, 1.09)	0.98 (0.89, 1.07)	0.98 (0.89, 1.07)
Q3	33.4 (10.0)	0.88 (0.76, 1.02)	0.97 (0.85, 1.11)	0.97 (0.89, 1.06)	0.97 (0.89, 1.06)
Q4	31.9 (9.9)	0.90 (0.78, 1.04)	0.97 (0.85, 1.11)	0.97 (0.89, 1.05)	0.97 (0.89, 1.05)
Q5	34.6 (10.7)	0.91 (0.79, 1.06)	0.93 (0.82, 1.06)	0.98 (0.90, 1.07)	0.98 (0.90, 1.07)
P_{trend}[e]		0.28	0.37	0.58	0.58
Factor 2: Agriculture					
Q1	33.4 (6.2)	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)
Q2	29.8 (6.5)	1.00 (0.87, 1.16)	0.98 (0.86, 1.11)	1.00 (0.89, 1.14)	1.00 (0.88, 1.13)
Q3	29.1 (8.5)	1.05 (0.91, 1.21)	0.96 (0.85, 1.09)	1.01 (0.89, 1.14)	1.00 (0.89, 1.13)
Q4	30.0 (10.6)	1.06 (0.91, 1.22)	0.99 (0.87, 1.12)	0.99 (0.87, 1.12)	0.98 (0.87, 1.11)
Q5	40.0 (12.9)	0.78 (0.66, 0.92)	0.80 (0.68, 0.94)	0.89 (0.77, 1.03)	0.90 (0.78, 1.04)
P_{trend}[e]		0.024	0.034	0.11	0.18
Factor 3: Light indoor activity					
Q1	27.3 (10.3)	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)
Q2	32.2 (10.6)	0.92 (0.79, 1.07)	0.93 (0.82, 1.06)	0.96 (0.88, 1.05)	0.97 (0.89, 1.06)
Q3	32.4 (10.9)	0.90 (0.77, 1.05)	0.89 (0.78, 1.01)	0.93 (0.85, 1.02)	0.94 (0.86, 1.03)
Q4	34.1 (8.2)	0.93 (0.80, 1.08)	0.88 (0.78, 1.00)	0.93 (0.85, 1.02)	0.94 (0.86, 1.03)
Q5	36.3 (8.0)	1.04 (0.90, 1.20)	0.92 (0.82, 1.03)	0.95 (0.87, 1.03)	0.96 (0.87, 1.05)
P_{trend}[e]		0.58	0.10	0.16	0.29
Factor 4: Manual labor					
Q1	32.4 (9.2)	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)
Q2	30.5 (7.8)	0.97 (0.85, 1.11)	1.04 (0.93, 1.17)	1.02 (0.91, 1.15)	1.01 (0.90, 1.13)
Q3	29.8 (8.5)	0.94 (0.82, 1.07)	0.97 (0.86, 1.10)	1.00 (0.89, 1.13)	0.99 (0.88, 1.12)
Q4	31.6 (10.0)	0.74 (0.64, 0.87)	0.88 (0.76, 1.02)	0.91 (0.79, 1.05)	0.92 (0.80, 1.05)
Q5	38.0 (12.4)	0.64 (0.54, 0.75)	0.82 (0.70, 0.97)	0.88 (0.75, 1.03)	0.90 (0.78, 1.04)
P_{trend}[e]		<0.001	0.006	0.053	0.066

Abbreviations: MET — metabolic equivalent.
[a] Model 1 — Unadjusted.
[b] Model 2 — Adjusted for age, sex and urbanicity.
[c] Model 3 — Adjusted for age, sex, urbanicity, income, current smoking status, family history of diabetes, and family history of hypertension.
[d] Model 4 — Adjusted for age, sex, urbanicity, income, current smoking status, family history of diabetes, family history of hypertension, and total METs.
[e] P_{trend} is from Wald test of quintiles of METs/day modeled as a continuous variable.

Table 4
Least squares means and 95% confidence intervals of components of metabolic syndrome by quintiles of total METs of activity per day and quintiles of scores for each physical activity pattern, Costa Rica, 1994–2004.

	Waist circumference (cm)	Triglycerides (mg/dL)	HDL cholesterol (mg/dL)	Systolic blood pressure (mm Hg)	Diastolic blood pressure (mm Hg)	Fasting blood glucose (mg/dL)
Total METs						
Q1	91.9 (90.9, 93.0)	230.0 (215.1, 244.9)*	42.0 (41.0, 43.0)*	136.7 (134.5, 138.9)	82.3 (81.2, 83.4)	85.2 (81.5, 88.8)
Q2	91.3 (90.3, 92.4)	227.1 (212.7, 241.5)	40.4 (39.5, 41.4)	135.9 (133.8, 138.0)	82.2 (81.1, 83.3)	83.4 (79.9, 86.9)
Q3	90.8 (89.8, 91.9)	226.1 (211.4, 240.8)	40.9 (39.9, 41.8)	135.2 (133.0, 137.3)	81.8 (80.7, 82.9)	83.1 (79.5, 86.7)
Q4	90.9 (89.9, 92.0)	222.4 (207.9, 236.9)	41.3 (40.3, 42.2)	138.0 (135.9, 140.2)*	82.1 (81.0, 83.2)	80.8 (77.2, 84.3)
Q5	90.8 (89.8, 91.9)	208.9 (194.5, 223.4)	40.5 (39.6, 41.5)	134.5 (133.3, 136.6)	80.8 (79.7, 81.9)	82.2 (78.7, 85.8)
P_{trend}	0.12	0.047	0.17	0.51	0.089	0.14
Factor 1 (rest/sleep)						
Q1	91.6 (90.5, 92.6)	222.6 (208.0, 237.2)	41.2 (40.3, 42.2)	136.0 (134.9, 138.2)	82.2 (81.1, 83.4)	89.1 (85.5, 92.6)**
Q2	91.9 (90.8, 92.9)	220.7 (206.0, 235.4)	40.5 (39.5, 41.5)	136.4 (134.3, 138.6)	82.2 (81.1, 83.3)	80.1 (76.6, 83.7)
Q3	90.8 (89.7, 91.9)	229.1 (214.4, 243.8)	42.1 (41.2, 43.1)**	137.6 (135.4, 139.8)	82.1 (80.9, 83.2)	81.1 (77.5, 84.7)
Q4	90.6 (89.6, 91.6)	220.6 (206.4, 234.9)	40.9 (40.0, 41.8)	134.1 (132.0, 136.3)	81.7 (80.6, 82.8)	82.3 (78.8, 85.7)
Q5	90.9 (89.9, 92.0)	220.2 (205.7, 234.7)	40.3 (39.3, 41.2)	136.0 (133.9, 138.2)	80.9 (79.8, 82.0)	81.7 (78.2, 85.3)
P_{trend}	0.11	0.83	0.33	0.49	0.074	0.029
Factor 2 (agriculture)						
Q1	91.4 (90.3, 92.5)	236.4 (221.5, 251.4)*	41.2 (40.2, 42.2)	136.2 (134.1, 138.5)	81.8 (80.6, 82.9)	85.2 (81.5, 88.8)
Q2	91.3 (90.3, 92.4)	223.5 (209.1, 237.9)	40.4 (39.5, 41.4)	136.0 (133.9, 138.2)	82.0 (80.9, 83.1)	83.5 (79.9, 87.0)
Q3	91.4 (90.4, 92.5)	219.6 (204.9, 234.3)	40.8 (39.9, 41.8)	136.4 (134.3, 138.6)	81.9 (80.8, 83.0)	84.3 (80.7, 87.9)
Q4	91.4 (90.3, 92.4)	225.8 (211.1, 240.5)	41.3 (40.4, 42.3)	137.2 (135.0, 139.3)	82.5 (81.4, 83.7)	81.0 (77.4, 84.6)
Q5	90.3 (89.3, 91.4)	208.8 (194.0, 223.5)	41.2 (40.3, 42.2)	134.4 (132.2, 136.5)	81.0 (79.9, 82.1)	80.7 (77.1, 84.3)
P_{trend}	0.25	0.033	0.49	0.47	0.62	0.054
Factor 3 (light indoor activity)						
Q1	92.8 (91.8, 93.9)***	232.9 (218.4, 247.5)*	41.0 (41.1, 42.0)	135.6 (133.4, 137.7)	81.0 (79.9, 82.1)	89.5 (86.0, 93.1)***
Q2	91.7 (90.7, 92.8)*	226.2 (219.3, 241.1)	41.3 (40.3, 42.3)	136.0 (133.8, 138.3)	82.2 (81.1, 83.4)	84.9 (81.3, 88.6)*
Q3	91.0 (90.0, 92.1)	216.1 (201.4, 230.8)	40.9 (39.9, 41.9)	136.2 (134.0, 138.3)	82.1 (80.9, 83.2)	79.8 (76.2, 83.4)
Q4	90.5 (89.4, 91.5)	230.1 (215.5, 244.7)*	41.4 (40.4, 42.3)	135.1 (132.9, 137.3)	81.5 (80.4, 82.6)	81.2 (77.6, 84.7)
Q5	89.8 (88.7, 90.8)	208.3 (193.4, 223.2)	40.5 (39.5, 41.5)	137.2 (135.0, 139.4)	82.3 (81.2, 83.4)	79.1 (75.5, 82.7)
P_{trend}	<0.001	0.063	0.57	0.53	0.28	<0.001
Factor 4 (manual labor)						
Q1	92.6 (91.5, 93.7)***	233.1 (218.1, 248.0)*	40.1 (39.1, 41.1)	135.4 (133.2, 137.6)	81.2 (80.1, 82.3)	83.8 (80.2, 87.4)
Q2	91.7 (90.6, 92.7)*	227.6 (213.0, 242.2)	40.8 (39.9, 41.8)	136.7 (134.5, 138.8)	82.2 (81.1, 83.3)	84.6 (81.0, 88.2)
Q3	91.3 (90.2, 92.3)	220.5 (205.7, 235.3)	41.6 (40.6, 42.5)	138.8 (136.6, 141.0)*	83.2 (82.0, 84.3)*	82.0 (78.4, 85.5)
Q4	90.3 (89.2, 91.3)	221.3 (206.8, 235.7)	41.6 (40.6, 42.5)	133.9 (131.7, 136.0)	81.2 (80.1, 82.3)	81.6 (78.1, 85.1)
Q5	90.0 (88.9, 91.0)	211.2 (196.4, 225.9)	41.2 (40.3, 42.2)	135.5 (133.3, 137.7)	81.4 (80.3, 82.5)	82.5 (78.9, 86.1)
P_{trend}	<0.001	0.040	0.095	0.49	0.77	0.34

All models adjusted for age, sex, urbanicity, income, family history of diabetes, family history of hypertension, and current smoking status. P_{trend} is from Wald test of quintiles of METs/day of physical activity pattern score modeled as a continuous variable. Abbreviations: HDL — high density lipoprotein; MET — metabolic equivalent.
* $P < 0.05$ for differences from Q5.
** $P < 0.01$ for differences from Q5.
*** $P < 0.001$ for differences from Q5.

fasting blood glucose ($P_{trend} = 0.029$), driven by high values in participants in the lowest rest/sleep pattern scores; and marginally associated with lower diastolic blood pressure ($P_{trend} = 0.074$). Higher scores on the agriculture pattern were associated with lower triglycerides ($P_{trend} = 0.033$), and marginally associated with lower fasting blood glucose ($P_{trend} = 0.054$). Higher levels of light indoor activity were associated with lower waist circumference ($P_{trend} < 0.001$) and fasting blood glucose ($P_{trend} < 0.001$) and marginally associated with lower triglyceride levels. Higher levels of manual labor were associated with lower waist circumference ($P_{trend} < 0.001$) and triglycerides ($P_{trend} = 0.04$), and marginally associated with higher HDL cholesterol ($P_{trend} = 0.095$).

Discussion

This study examined whether total physical activity or any of four physical activity patterns identified through principal components analysis were associated with metabolic syndrome or its components. We found no association between total physical activity and prevalence of metabolic syndrome; however, higher scores on the manual labor pattern were marginally associated with lower metabolic syndrome prevalence and with lower waist circumference and plasma triglycerides. Although none of the other physical activity patterns was associated with metabolic syndrome in fully-adjusted analyses, higher scores on the agriculture pattern were associated with lower triglycerides; higher scores on the light indoor activity pattern were associated with lower waist circumference and fasting blood glucose; higher rest/sleep scores were associated with lower fasting blood glucose; and higher total activity was associated with lower triglycerides.

Little is known about the association between total physical activity and metabolic syndrome; however, our finding of no association is not consistent with findings of lower prevalence of metabolic syndrome in Portuguese adults in the highest tertile of total physical activity compared to those in the lowest tertile [odds ratio (OR): 0.63, 95% CI: 0.43, 0.94 for women; OR: 0.55, 95% CI: 0.33, 0.91 for men] (Santos et al., 2007). Several previous studies have reported inverse associations between leisure-time physical activity (LTPA) and metabolic syndrome (Cho et al., 2009; Halldin et al., 2007; He et al., 2013), including a meta-analysis of prospective studies that reported a 20% lower risk of metabolic syndrome associated with the highest levels of LTPA relative to the lowest [relative risk (RR) for high vs. low LTPA: 0.80, 95% CI: 0.75, 0.85] but a weaker association for moderate amounts of LTPA (He et al., 2013).

LTPA was not independently captured in the patterns assessed here; however, we conducted a sensitivity analysis of METs per day of team, individual, and other sports combined with METs per day of walking on flat terrain to approximate LTPA. Although we observed an inverse association between METs per day of LTPA and metabolic syndrome prevalence in unadjusted analyses, we observed no association after adding covariates to the models (Supplementary Table A). However, LTPA was inversely associated with both waist circumference and triglycerides in adjusted models (Supplementary Table B).

In additional sensitivity analyses grouping similar activities together (rather than using scores on patterns identified through principal components analysis) into sleep and rest, light activity, and manual and agricultural labor activities, no association was evident between quintiles of METs in any of these activity groups and metabolic syndrome (Supplementary Table A). Positive associations were evident between time spent sleeping, napping, and lying in bed and waist circumference, triglycerides and fasting blood glucose (Supplementary Table B); however, this association could be observed due to reverse causality or confounded by health status. Participants reporting the highest levels of light activity had the lowest fasting blood glucose, and higher levels of manual and agricultural labor were associated with lower waist circumference, systolic and diastolic blood pressure (Supplementary Table B).

In our main analyses, the strongest associations observed were for an inverse association between high scores on the manual labor pattern and metabolic syndrome prevalence. Previous findings for work-related physical activity and metabolic syndrome are mixed. Santos et al. found an inverse association between METs of work-related activity and metabolic syndrome in Spanish women, but not in men (Santos et al., 2007), and Sanchez-Chaparro, et al. reported higher prevalence of metabolic syndrome in women in manual or blue-collar occupations relative to those in non-manual or white-collar positions, but no difference for men (Sanchez-Chaparro et al., 2008).

Although there is limited research linking higher levels of manual labor with lower prevalence of metabolic syndrome, previous work suggests that strength training and increased muscle mass are protective against metabolic syndrome and its components through their beneficial effects on insulin resistance, fatty acid metabolism and resting metabolic rate (Green et al., 2004; Jurca et al., 2004; Kelley, 2005; Lakka and Laaksonen, 2007). Previous work in the United States suggests that working in occupations with the highest strength demands led to weight gain due to developing additional muscle mass, particularly in men (Lakdawalla and Philipson, 2007). To the extent that participants with the highest scores on the manual labor pattern have greater muscle mass than those with lower manual labor scores, this could provide a plausible explanation for the observed association between higher scores on the manual labor pattern and lower prevalence of metabolic syndrome and its components than those with lower manual labor scores. Additional muscle mass might also explain the observed association between higher scores on the agricultural pattern and lower triglycerides.

Although higher scores on the light indoor activity pattern were not associated with prevalence of metabolic syndrome, they were associated with smaller waist circumference and lower fasting blood glucose. This is consistent with previous findings of an association between objectively measured light-intensity activity and both waist circumference (Healy et al., 2008) and blood glucose levels (Healy et al., 2007). Engaging in light-intensity activities could be a promising strategy to reduce cardiometabolic risk, particularly to the extent that they displace sedentary time, which is associated with cardiometabolic risk factors regardless of total activity levels (Bankoski et al., 2011; Hamilton et al., 2007).

In sensitivity analyses adding BMI to the adjusted models of total physical activity, physical activity patterns and metabolic syndrome presented in Table 3, all prevalence ratios attenuated to between 0.98 and 1.01 (Supplementary Table C). To the extent the results presented here suggest an inverse association between total physical activity, physical activity patterns and metabolic syndrome, it is likely due to beneficial effects on body mass index (BMI).

Several limitations of this study must be addressed. The cross-sectional design limits inferences with regard to whether physical activity patterns may have influenced whether participants had metabolic syndrome, or vice versa. Although the components of metabolic syndrome were objectively measured, the physical activity measures were based on self-reported information and are subject to measurement error and misclassification. In this population, the highest levels of physical activity were observed among participants who engaged in the highest levels of manual labor and had the lowest household incomes. These individuals could also have other risk factors for metabolic syndrome that are not effectively accounted for in our models. Further, although this population is representative of Costa Rican adults within matching strata, the generalizability of these results and the identified activity patterns to other populations could be limited.

Strengths of this study include the detailed questionnaire, including several measures of occupational and leisure-time physical activity, diet, and medical history. Objective measurements of waist circumference, blood pressure, fasting blood glucose, triglycerides and HDL cholesterol were used to assess whether participants had metabolic syndrome. The population-based sampling frame and high response rate of these control participants make this sample reasonably representative of the source population of Costa Rican adults with no history of MI within matching strata for the case–control study.

Conclusion

These results have important public health implications because they suggest that all physical activities are not created equal when it comes to their potential to affect cardiometabolic risk. Specifically, our findings that that higher scores on the manual labor, agricultural, and light indoor activity patterns are inversely associated with metabolic syndrome components suggest that activity-related benefits on cardiometabolic risk could come from strength-related activities and reducing sedentary time.

Conflict of interest
The authors have no conflicts of interest to disclose.

Acknowledgments

T.H. analyzed data and wrote the manuscript. J.G. analyzed data and reviewed/edited the manuscript. H.C. managed data collection and reviewed/edited manuscript. A.B. collaborated on statistical analysis and analysis plan, contributed to the organization, presentation and communication of findings, and reviewed/edited the manuscript. All authors critically reviewed the report. T.H. is the guarantor of this work and, as such, had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.ypmed.2014.11.006.

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