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Steps/day and metabolic syndrome in African American adults: The Jackson Heart Study[☆]

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Abstract

Objective—To examine the relationship between pedometer-measured step count data and the Metabolic Syndrome (MetS) in African American adults.

Method—379 African American adults (mean age 60.1 years; 60% female) enrolled in the Jackson Heart Study (Jackson, MS) from 2000 to 2004 provided sufficient pedometer data for inclusion in this analysis. MetS was classified according to the International Diabetes Federation Task Force on Epidemiology and Prevention.

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Results—Using steps/day categorized as tertiles (<3717 (referent), 3717–6238, >6238), participants taking 3717–6238 (Odds Ratio (OR)(95% Confidence Interval (CI)) = 0.34 (0.19, 0.61)) and >6238 steps/day (OR(95% CI) = 0.43 (0.23, 0.78)) had lower odds of having MetS compared to participants in the lowest tertile. Using previously suggested steps/day cut-points (<2500 (referent), 2500–4999, 5000–7499, 7500), the odds of having MetS were lower for participants taking 2500–4999 (OR(95% CI) = 0.32 (0.14, 0.72)), 5000–7499 (OR(95% CI) = 0.22 (0.09, 0.53)), and >7500 (OR(95% CI) = 0.26 (0.11, 0.65)) steps/day compared to those taking <2500 steps/day.

Conclusion—Compared to lower levels, higher levels of steps/day are associated with a lower prevalence of MetS in this older African American population.

Keywords

African Americans; Pedometer; Cardiovascular disease risk; Health disparities; Behavior

Introduction

In the past decade, the prevalence of metabolic syndrome (MetS) has increased in African American men and women (Churilla et al., 2007; Mozumdar and Liguori, 2011). The impact of this increase could lead to an even greater cardiometabolic burden in this population that is already facing health disparities in chronic disease (Cowie et al., 2009; Lloyd-Jones et al., 2009). Physical activity (PA) is a modifiable behavioral risk factor for MetS. Although self-reported PA has been associated with MetS in African Americans (Irwin et al., 2002), some studies of objectively measured PA have not found relationships with most components of MetS (Crane and Wallace, 2007; Panton et al., 2007), have not measured MetS (Crane and Wallace, 2007; Hornbuckle et al., 2005; Panton et al., 2007), or have not controlled for the effect of ethnicity (Camhi et al., 2011; Churilla and Fitzhugh, 2009). Thus, the relationship between PA and MetS has not been clearly demonstrated in African Americans. Therefore, the purpose of this study is to assess the relationship between pedometer measured step count data and MetS in a large sample of African American adults.

Methods

Participants

The participants in the study were enrolled in the Diet and Physical Activity Sub-study (DPASS) of the Jackson Heart Study (JHS). Specific details related to the JHS (Fuqua et al., 2005; Taylor et al., 2005) and the DPASS component of the JHS (Carithers et al., 2005; Dubbert et al., 2005) can be found elsewhere. Three academic institutions collaborated on the project: Jackson State University, the University of Mississippi Medical Center, and Tougaloo College. The research was approved by the Institutional Review Boards of all three institutions. All participants provided written informed consent.

Clinical procedures

All procedures were conducted after participants had undergone an 8-hour fast and abstention from caffeine, alcohol, heavy physical activity, and smoking. Participants were

instructed to bring in all medications taken during the two weeks prior to their clinic exam. Height was measured without shoes and recorded to the nearest centimeter. Participants stood with their feet together and head held in the Frankfurt plane. Weight was measured on a balance scale, in light clothing, without shoes, and recorded to the nearest 0.5 kg. BMI was calculated as weight in kilograms divided by height in square meters. Waist circumference was measured at the level of the umbilicus using anthropometric tape. The measurement was recorded to the nearest centimeter upon the end of exhalation. A standard Littman stethoscope and a standard Hawksley random zero sphygmomanometer were used to measure blood pressure. Blood pressure was calculated as the average of two measurements taken 1 min apart, after the participant had rested for 5 min in a recumbent position in a quiet room. Approximately 97 mL of blood was drawn from each participant, from which serum high density cholesterol (HDL) and triglycerides, and plasma blood glucose levels were measured. All blood was collected within a 1-hour time frame.

Metabolic syndrome

MetS was defined according to the Joint International Diabetes Federation Task Force on Epidemiology and Prevention (Alberti et al., 2009). Thus, any three of the following five criteria were required to meet MetS definition: (1) large waist circumference (≥ 102 cm for men and ≥ 88 cm for women); (2) high triglyceride levels (≥ 150 mg/dL or on drug treatment); (3) low HDL cholesterol levels (≤ 40 mg/dL for men and ≤ 50 mg/dL in women or on drug treatment); (4) elevated blood pressure (≥ 130 mm Hg systolic or ≥ 85 mm Hg diastolic or on drug treatment); or, (5) elevated fasting glucose (≥ 100 mg/dL or on drug treatment).

Pedometer

The Yamax SW-200 pedometer (Yamax Corp., Tokyo, Japan) was utilized in the study. This pedometer has been shown to be a reliable and valid measurement of steps/day (Crouter et al., 2003; Schneider et al., 2003).

Pedometer monitoring

Participants were scheduled for six clinic visits as part of the DPASS. The pedometer-determined PA assessments were conducted on a maximum of three of these clinic visits. A week before their third, fourth, and fifth scheduled DPASS clinic visits participants were mailed the pedometer and a step log to record their daily steps at the end of each day. They were instructed to wear the pedometer at their waist for a 3-day monitoring period, which consisted of three consecutive days. Participants were asked to reset the pedometer at the beginning of each day and to remove it only at night for sleeping or for water activities, such as bathing or swimming. Participants were also instructed to record times when the device was not worn. Participants returned the log and the pedometer at the subsequently scheduled clinic visit. This procedure was repeated for a maximum of three separate pedometer assessment occasions. The DPASS clinic visits (and thus the pedometer assessments) were separated by approximately one month.

Data treatment and statistical analysis

Participants were included in this analysis if they had logged all three required days of pedometer data for at least one of the required three assessment periods. Step counts <500 on any single day were considered outliers (Julius et al., 2011; Tudor-Locke et al., 2011a) and therefore were excluded. Data from any given assessment period with less than three days were excluded because they did not adhere to study protocol and because three days of measurement demonstrates the greatest reliability (Newton et al., 2012). Initially, there were 481 DPASS participants with at least 1 day of logged pedometer data; 91 participants were excluded because their pedometer data did not meet the inclusion criteria, leaving 390 DPASS participants (aged 37–81 years) with valid pedometer data. An additional 11 were excluded because of missing demographic or MetS risk factor information. Therefore, this analysis was based on data from 379 participants (78.8% of initial DPASS sample); 130 of these participants had data from three pedometer assessments, 136 had data from two assessments, and 113 had data from one assessment. Because there were single and multiple assessments, mean steps/day was calculated by averaging step counts over the total number of days (3, 6, or 9) of pedometer assessment (1, 2, or 3). Both single three-day assessments and multiple three-day assessments have been shown to be reliable (Kang et al., 2009; Newton et al., 2012).

Categorical steps/day

Steps/day was categorized using two different criteria: tertiles and previously suggested cut-points. Tertile 1 was <3717 steps/day (n = 127), Tertile 2 was 3717–6238 steps/day (n = 126), and Tertile 3 was >6238 steps/day (n = 126). Four distinct categories were utilized when steps/day was classified based on previously suggested cut-points: ‘basal activity’ (<2500 steps/day, n = 58), ‘limited activity’ (2500–4999 steps/day, n = 139), ‘low active’ (5000–7499 steps/day, n = 96), and ‘somewhat active’ to ‘highly active’ (≥7500 steps/day, n = 86) (Tudor-Locke et al., 2009, 2011b).

Chi-square analysis (for categorical variables) and ANOVA (for continuous variables) were used to assess significant differences in demographic characteristics between participants across tertiles. Logistic regression was used to assess the relationship between categorical steps/day and the presence or absence of (1) MetS and (2) each of the five criteria components of MetS. The results were expressed as Odds Ratios (OR) with accompanying 95% confidence intervals. Two models were tested: Model 1, results were adjusted for age and sex; Model 2, results were further adjusted for education, alcohol consumption, smoking, and BMI.

Continuous steps/day

Logistic regression was also used to assess the relationship between steps/day as a continuous variable and the presence or absence of MetS. These analyses mirrored the analyses for categorically determined steps. The results were expressed as ORs per 1000 steps/day increments.

Results

Demographic characteristics

The demographic characteristics of the sample can be seen in Table 1. There are statistical differences across various tertiles for the components of MetS. There was no difference in the prevalence of MetS ($\chi^2 = 0.27$; $p = .61$) between those with and without complete pedometer data.

Categorical steps/day: Tertiles

In Model 1, controlling for demographic factors, participants who took 3717–6238 (Tertile2) and >6238 (Tertile 3) steps/day, respectively, had 70% lower odds of having MetS (p values < 0.001) compared to participants in the lowest tertile (<3717 steps/day), respectively (Table 2). The odds were 66% and 57% lower (p values <0.001) in Model 2.

There were 54% and 52% (p values < 0.05) lower odds of having elevated blood glucose for participants in the Tertiles 2 and 3, respectively, compared to participants in the lowest tertile in Model 1. These values were 53% and 48% (p values < 0.05) in Model 2. There were 70% and 54% (p values < 0.05) lower odds of having high blood pressure for participants in the two highest tertiles compared to participants in the lowest tertile in Model 1. Only those taking 3717–6238 steps/day retained their lower odds (66%, p value < 0.01) in Model 2. Compared to participants in the lowest tertile in Model 1, the odds were 65% and 60% lower (p values < 0.001) for those taking 3717–6238 and >6238 steps/day, respectively, for large waist circumference, and were lower by 54% (p < 0.01) for those taking >6238 steps/day for low HDL. These odds were not significant in Model 2. The odds for having elevated triglycerides were not significantly different between participants in different steps/day tertiles regardless of the model tested (all p values >0.102).

Categorical steps/day: Previously suggested cut-points

In Model 1, participants classified as ‘limited activity’ (2500–4999 steps/day), ‘low active’ (5000–7499 steps/day), and ‘somewhat’ to ‘highly active’ (>7500 steps/day) had 72%, 83%, and 83% lower odds (p values < 0.01), respectively, of having MetS compared to participants in the referent basal activity category (<2500 steps/day). In Model 2, these values were 68%, 78%, and 74% (p values < 0.01), respectively (Table 3).

In Model 1, participants classified as ‘limited activity’, ‘low active’, and ‘somewhat’ to ‘highly active’ had, respectively, 67%, 71%, and 74% lower odds (p values < 0.001) of having elevated glucose values compared to participants in the basal activity category. These relationships were virtually unchanged in Model 2 (66%, 71%, and 73%). In Model 1, participants classified as ‘low active’ and ‘somewhat active’ to ‘highly active’ had 73% and 76% lower odds for having a large waist circumference (p values <0.01) compared to participants in the basal activity category. This effect was not present in Model 2. The odds for having elevated triglycerides, low HDL, and high blood pressure were not significantly different between participants in the different steps/day-defined physical activity categories regardless of the model tested (all p values > 0.080).

Continuous steps/day

The two models tested demonstrated that the odds of having MetS were 12% and 7% lower (p values < 0.05), respectively, for every 1000 steps/day increment. In Model 1, the odds of having a large waist circumference ($p < 0.01$), low HDL ($p < 0.05$), and elevated glucose ($p < 0.05$) were lower for every additional 1000 steps/day. There were non-significant trends for the odds of having low HDL (OR (95% CI) = 0.93 (0.86, 1.0); $p = 0.077$) and elevated glucose (OR (95% CI) = (0.87, 1.0); $p = 0.059$) to be reduced with each 1000 steps/day increment in Model 2.

Discussion

The current study demonstrated an inverse relationship between pedometer-determined physical activity and MetS in African American adults. This relationship was apparent when steps/day was analyzed according to two different categorical variables and as a continuous variable. The findings of the study also indicate that categories of higher steps/day are associated with lower odds of having elevated glucose. Therefore, it is plausible that even small increments, approximately 1000 steps/day, above a referent level (3700 steps/day (tertiles) or 2500 steps/day (cut-point)) are associated with more favorable biomarkers of cardiometabolic health in this population.

The odds of having MetS and elevated blood glucose were significantly lower among those taking >3700 steps/day according to the tertiles and those taking >2500 steps/day according to the cut-points. These individuals had 57%–78% lower odds of having MetS and 48%–73% lower odds of having elevated blood glucose levels compared to those taking the fewest steps. These benefits were associated with relatively small incrementally higher values of accumulated steps/day. In fact, the findings indicate that even those who were classified within the ‘limited activity’ category had significantly lower odds than those in the lowest category (‘basal activity’). However, elevated glucose was the only individual component of MetS that was associated with steps/day. Increased steps/day lowered the odds of having each of the individual components of MetS when age and gender were covariates, but these associations were nullified when education, alcohol, smoking and BMI were introduced. In fact, BMI was significantly associated with the vast majority of the individual components in the final models. This suggests that compared to steps/day, BMI was more strongly associated with the individual components of MetS in this older, largely sedentary, African American population. The fact that this sample was largely homogenous in terms of accumulated steps/day (i.e., few took $> 10,000$ steps/day) may explain this finding.

Other studies have assessed the relationship between step counts and cardiometabolic variables (i.e. body composition, blood pressure and blood glucose) in African American adults (Crane and Wallace, 2007; Hornbuckle et al., 2005; Panton et al., 2007). These studies have repeatedly shown relationships between steps/day and body composition variables (including waist circumference), but have not documented a relationship between steps/day and cardiometabolic variables (blood pressure, cholesterol, diabetes, triglycerides, low density lipoproteins (LDL-C), fibrinogen, and C-reactive protein). The current study is consistent with these previous studies in terms of showing a relationship between steps/day

and body composition variables (i.e. those with lower steps/day had a larger waist circumference) and that there were few apparent relationships between steps/day and cardiometabolic variables (i.e. the individual components of MetS), with the exception of glucose levels. Since none of the previous studies assessed for the presence or absence of MetS, the current findings extend knowledge by showing lower odds of prevalent MetS with steps/day above the referent category (tertile or cut-point). In addition, the current study overcomes methodological limitations of previous studies of this population by having a larger sample size and including both men and women. Nonetheless, more studies are needed in order to draw definitive conclusions regarding the relationship between steps/day and risk for cardiometabolic disorders in African Americans. Future research should focus on longitudinal investigations given that all studies in African Americans thus far have been cross-sectional.

Two different approaches for categorizing steps/day were utilized: distribution-specific tertiles and previously suggested cut-points. The former approach classifies the data into categories that best fit the JHS population, while the latter approach enables comparisons to other studies that use the previously suggested cut-points. The odds of having MetS and elevated blood glucose were significantly lower among those taking >3700 steps/day according to the tertiles and those taking >2500 steps/day according to the cut-points. These findings are similar to other investigations demonstrating an inverse relationship between objectively measured physical activity and MetS (Bankoski et al., 2011; Camhi et al., 2011; Churilla and Fitzhugh, 2012; Julius et al., 2011; Sisson et al., 2010; Strath et al., 2007; Woolf et al., 2008). In addition, previous research involving Caucasian adults has also shown that steps/day in the 'limited activity' (2500–4999 steps/day) and 'low active' (5000–7499 steps/day) ranges was associated with lower prevalence of MetS relative to the referent steps/day category (Camhi et al., 2011; Churilla and Fitzhugh, 2012; Strath et al., 2007; Tudor-Locke et al., 2009; Tudor-Locke et al., 2011b). These findings are important because when combined with the current results they suggest that regardless of race, low levels of activity are associated with cardiometabolic benefits, relative to taking fewer steps/day.

The study should be interpreted in the context of its limitations. First, we relied on the participants to self-report the data from the pedometer. Although the pedometers provide an objective assessment of steps taken, participant error in recording the steps remains a possibility, ultimately reducing its objectivity as a measurement. However, self-recorded pedometer-determined steps/day is known to correlate strongly ($r = 0.86$) with the blinded and independently downloaded data derived from concurrently worn accelerometers (Tudor-Locke et al., 2002). Further, we have previously reported that participant's self-record pedometer data are within 4.4 steps when compared to blinded values from the same instrument's internal memory record (Tudor-Locke et al., 2012). Almost 20% of participants were excluded because they did not provide three consecutive days of pedometer data. These individuals may have different PA habits and engage in less PA compared to the participants who provided usable data. People who wear objective instruments for fewer days are less active than those who wear them for more days (Tudor-Locke et al., 2009). However, the average steps/day ($M(SD) = 5610(3427)$) of participants included in this analysis was similar to those reported in other studies of African Americans ($M = 5412, 5747, \text{ and } 4355$) (Crane and Wallace, 2007; Hornbuckle et al., 2005; Panton et al., 2007).

Although larger than other studies of African American adults, the sample size could be considered to be relatively small. We did not control for medication use in this study. Over 60% of the participants were taking a medication designed to reduce blood pressure, triglycerides, or diabetes, or increase HDL-C. This could explain why we found few associations with the individual components of MetS. Another limitation is that the adults in the sample were on average 60 years old and findings may not generalize to younger African Americans. Finally, the data is cross-sectional which limits our ability to make causal inferences.

Conclusion

The current study is one of the first to show that relatively higher steps/day is associated with lower odds of having MetS in African American adults. We also demonstrated that relatively higher steps/day is associated with reduced odds of having elevated blood glucose. The data suggest that there is less prevalent MetS and its unfavorable components among African American men and women who accumulate physical activity above a basal level, in that taking >3700 (tertiles) or >2500 (cut points) steps/day is associated with lower odds of having MetS and elevated glucose levels. Accumulating <2500 steps is considered indicative of 'basal' activity, and 3700 steps/day is within the 'limited activity' classification, and both are considered to be representative of a sedentary lifestyle compared to people who take much higher levels of steps/day. In the inactive and older JHS DPASS population, although achieving the 'low active' or 'somewhat active' categories are associated with at least some degree of improved cardiometabolic health over basal levels, individuals should be encouraged to achieve as high of levels as possible as this will likely result in even greater health benefits.

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Table 1

Characteristics of JHS DPASS^a (2000–2003) sample by steps/day tertiles^{b,c}.

	n	All	Tertiles			p
			<3717	3717–6238	>238	
		379	127	126	126	
Characteristic						
Sex, % (women)	60.2		68.5%	65.1%	46.8%	<0.001
Age (years)	60.1 (9.6)		63.8 ^a	59.7 ^b	56.7 ^c	<0.001
Education, %						
<High school	18.3		26.8	16.8	11.1	0.002
High school	35.2		39.4	29.6	36.5	
>High school	46.5		33.9	54.6	52.4	
Smoking, %						
Never	64.9		68.5	69.8	56.4	0.067
Former	25.1		22.1	19.1	34.1	
Current	10.0		9.4	11.1	9.5	
Alcohol drinking in the past 12month, %						
No	55.1		72.4	58.9	50.7	<0.380
<1 drink per week	23.5		20.7	28.5	36.2	
1 drink per week	17.2		3.5	5.4	10.1	
Missing	4.2		3.5	7.1	2.9	
BMI (kg/m ²)	30.8 (6.7)		32.0 ^a	30.8 ^{ab}	29.7 ^b	0.019
Waist circumference (cm)	101.1 (16.3)		105.8 ^a	98.9 ^b	98.7 ^b	<0.001
Systolic blood pressure (mm Hg)	127.6 (17.2)		131.0 ^a	126.2 ^b	125.5 ^b	0.022
Diastolic blood pressure (mm Hg)	77.3 (10.9)		74.6 ^a	77.9 ^b	79.2 ^b	0.002
HDL cholesterol (mg/dL)	53.2 (15.0)		51.4	55.0	53.1	0.173
Triglycerides (mg/dL)	95.2 (69.4, 138.9)		127.3	110.5	107.6	0.217
Glucose (mg/dL)	96.0 (88, 107)		112.1 ^a	102.1 ^b	99.7 ^b	0.016
Hypertension (%)	72.7		84.9	69.8	63.2	<0.001
Diabetes, Type II (%)	24.6		38.4	19.1	16.3	<0.001

	Tertiles			<i>p</i>
	<3717	3717–6238	>6238	
All				
Metabolic Syndrome (%)	50.9	42.1	38.1	<0.001
Average steps/day	5610 (3427)	4929 ^b	9453 ^c	<0.001

^aJHS DPASS, Jackson Heart Study Diet and Physical Activity Substudy.

^bAge, BMI, waist circumference, systolic and diastolic blood pressure, cholesterol, and steps/day are reported as Mean (SD). Triglycerides and glucose are reported as median (interquartile range).

^cValues with different superscripts are significantly different from one another.

Table 2

Odds ratio of the presence of MetS in the JHS DPASS^a (2000–2003) using distribution-specific tertiles.

Tertile		Model 1 ^b OR (95% CI)	Model 2 ^b OR (95% CI)
1	<3717 steps/day	1	1
2	3717–6238 steps/day	0.30*** (0.18, 0.52)	0.34*** (0.19, 0.61)
3	>6238 steps/day	0.30*** (0.17, 0.53)	0.43** (0.23, 0.78)

^aJHS DPASS, Jackson Heart Study Diet and Physical Activity Substudy; MetS, Metabolic Syndrome.

^bModel 1 is adjusted for age and sex. Model 2 is adjusted for age, sex, education, alcohol consumption, smoking and BMI.

* Significant level at 0.05.

** Significant level at 0.01.

*** Significant level at 0.001.

Table 3

Odds ratio of the presence of MetS in the JHS DPASS^a (2000–2003) using commonly recommended cut-points.

Activity level	Recommended cut-point	Model 1 ^b OR (95% CI)	Model 2 ^b OR (95% CI)
Basal activity	<2500 steps/day	1	1
Limited activity	2500–4999 steps/day	0.28 *** (0.13, 0.60)	0.32 ** (0.14, 0.72)
Low active	5000 – 499 steps/day	0.17 *** (0.08, 0.39)	0.22 *** (0.09, 0.53)
Somewhat to highly active	>7500 steps/day	0.17 *** (0.08, 0.40)	0.26 ** (0.11, 0.65)

^a JHS DPASS, Jackson Heart Study Diet and Physical Activity Substudy; MetS, Metabolic Syndrome.

^b Model 1 is adjusted for age and sex. Model 2 is adjusted for age, sex, education, alcohol consumption, smoking and BMI.

* Significant level at 0.05.

** Significant level at 0.01.

*** Significant level at 0.001.