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Relationship of Weekly Activity Minutes to Metabolic Syndrome in Prediabetes: The Healthy Living Partnerships to Prevent Diabetes

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Abstract

Background—Physical inactivity contributes to metabolic syndrome (MetS) in overweight/obesity. However, little is known about this relationship in prediabetes.

Methods—The study purpose is to examine relationships between physical activity (PA) and MetS in prediabetes. The Healthy Living Partnerships to Prevent Diabetes tested a community translation of the Diabetes Prevention Program (DPP). Three hundred one overweight/obese prediabetics provided walking minutes/week (WM) and total activity minutes/week (AM) via the International Physical Activity Questionnaire. MetS was at least 3 of waist (men 102 cm, women 88 cm), triglycerides (≥ 150 mg-dl), blood pressure ($\geq 130/85$ mm Hg), glucose (≥ 100 mg-dl), and HDL (men < 40 mg-dl, women < 50 mg-dl).

Results—The sample was 57.5% female, 26.7% nonwhite/Hispanic, 57.9 ± 9.5 years and had a body mass index (BMI) 32.7 ± 4 kg·m². Sixty percent had MetS. Eighteen percent with MetS reported at least 150 AM compared with 29.8% of those without MetS. The odds of MetS was lower with greater AM ($P_{\text{trend}} = .041$) and WM ($P_{\text{trend}} = .024$). Odds of MetS with 0 WM were 2.08 ($P = .046$) and with no AM were 2.78 ($P = .009$) times those meeting goal. One hour additional WM led to 15 times lower MetS odds.

Conclusions—Meeting PA goals reduced MetS odds in this sample, which supported PA for prediabetes to prevent MetS.

Keywords

obesity; walking; physical activity

The current rates of overweight and obesity in the US are alarming, with 32% of adults falling into the obese category and 68% of US adults classified as overweight or obese.¹ The negative health consequences of overweight and obesity are numerous² and include metabolic syndrome (MetS), defined by the National Cholesterol Education Program (NCEP) Adult Treatment Panel III (ATP III) as the presence of 3 or more of the following criteria: elevated waist circumference (>102 cm for men, >88 cm for women), elevated triglycerides (>150 mg-dl), reduced high-density lipoprotein (HDL) cholesterol (<40 mg-dl in men, <50 mg-dl in women), elevated blood pressure (>130/85 mmHg) and/or elevated fasting glucose (>110 mg-dl).³ An update to these criteria was published in 2005 that reduced the criteria for fasting glucose to >100 mg-dl.⁴ The metabolic syndrome has been linked to an increased risk of cardiovascular disease and diabetes beyond the effects of adiposity.^{5–7} Furthermore, prevalence rates of diabetes, hypertension and cardiovascular disease are increasing and all are associated with overweight, obesity and the MetS.^{8,9} Physical inactivity is a major contributor to the development of MetS and PA interventions have been shown to reduce metabolic risk factors for coronary heart disease (CHD) and diabetes (DM).^{10–12}

In 2008, the Centers for Disease Control and Prevention (CDC) released the Physical Activity Guidelines Advisory Committee Report¹³ from which the Physical Activity Guidelines for Americans¹⁴ were developed. According to the report, the minimal amount of PA needed to prevent MetS is between 120 and 180 minutes of moderate intensity activity per week. According to 2007 Behavioral Risk Factor Surveillance System (BRFSS) data, 43.5% of adults met the new standards before their release, though the prevalence of meeting this recommendation has not been published since its release.¹⁵ Achieving this PA goal appears to reduce one's risk of developing MetS. Using data from NHANES, Churilla reported that those meeting the public health recommendation (>30 minutes 5 days per week of moderate activity OR >20 minutes, 3 days per week, of vigorous activity) were between 39%–46% less likely to have MetS, depending on the specific MetS definition examined.¹⁶ According to Sisson et al, measured steps per day was inversely related to MetS prevalence with 55.7% in the lowest active group (basal < 2500 steps) satisfying criteria for MetS compared with only 13.3% in the highest active group (>12,500 steps).¹⁷ In addition, there was a 10 to 13% reduction in odds of having MetS per additional 1000 recorded daily steps taken.¹⁷

Although the above studies indicate that increasing levels of physical activity are associated with lower risk for developing MetS, these data are based primarily on healthy samples. Prediabetes, defined as elevated blood glucose 100–125 mg-dl (American Diabetes Association),¹⁸ represents a preclinical diabetic state. Recent estimates indicate that approximately 79 million US adults have prediabetes¹⁹ and these individuals will develop diabetes at a rate of 10% per year.²⁰ Moreover, overweight and obese persons with prediabetes are at especially high risk of developing MetS, as they exhibit at least 1–2 (elevated fasting glucose and/or waist circumference) of the criteria for MetS.²¹ However, it is not clear whether differences in PA are associated with risk of MetS in this high risk group.

Purpose

The purpose of this study is to examine the relationship between physical activity and prevalent MetS at baseline in individuals with prediabetes enrolled in a group behavioral weight loss study. The Healthy Living Partnerships to Prevent Diabetes study (HELP PD) is a randomized, community-based trial testing the effectiveness of a community health worker (CHW) led translation of the DPP.²²

Methods

Design and Recruitment

Detailed descriptions of the design and recruitment strategies for the Healthy Living Partnerships to Prevent Diabetes (HELP PD) were previously published.^{22,23} In brief, HELP PD is a randomized, controlled trial of a CHW-led translation of the Diabetes Prevention Program (DPP) intervention.²² Community dwelling adults (n = 301) were recruited via mass mailing and screened by telephone and clinical assessments to rule out exclusion criteria (involved in a supervised weight loss program before study enrollment, history of diabetes mellitus, recent history of CVD, uncontrolled hypertension, pregnancy, chronic use of medications that significantly affect glucose metabolism, other chronic disease likely to limit lifespan, and other criteria likely to interfere with participation).²³ All participants were either overweight or obese ($25 \leq \text{BMI} < 40$) and were required to provide evidence of prediabetes on 2 occasions. Initial qualifying values could be an elevated fasting glucose between 95–125 mg·dl collected during the previous 3 months at the usual source of care, a nonfasting glucose between 120–199 mg·dl collected at a study information session, or a fasting glucose between 95–125 mg·dl collected at the General Clinical Research Center (GCRC) during a study screening visit. Each participant was required to have a confirmatory fasting blood glucose between 95–125 mg·dl collected during a screening visit at the GCRC. Other inclusion criteria included older than 21 years and not breast feeding or planning to become pregnant in the next 2 years.

After completing an IRB approved informed consent and all screening and baseline data collection procedures, eligible participants were randomized to an intensive lifestyle intervention or a usual care control group.²⁴ Individuals were enrolled for 24 months. Baseline data collection began August 2007 and ended April 2009. Follow-up data collection ended in May 2011. Data analysis began concurrently with data collection.

This study was approved by the Wake Forest University (Winston Salem, NC, USA) Institutional Review Board.

Data Collection

The recruitment and randomization process is illustrated in Figure 1. The tiered recruitment process yielded 301 randomized participants. Each participant visited the General Clinical Research Center at Wake Forest Baptist Medical Center for baseline and follow-up data collection. Blood was drawn; height, weight and waist circumference were measured; questionnaires assessing psychosocial variables, depression, health history and health related quality of life were completed and PA was evaluated by self-report.

Metabolic Syndrome—MetS was defined using the NCEP ATPIII criteria. Those identified as having MetS met at least 3 of the following criteria: elevated waist circumference (men ≥ 102 cm, women ≥ 88 cm); elevated triglycerides (≥ 150 mg·dl); reduced HDL cholesterol (men < 40 mg·dl, women < 50 mg·dl); elevated blood pressure ($\geq 130/85$ mm Hg) and/or elevated fasting glucose (≥ 100 mg·dl).⁴

International Physical Activity Questionnaire—Minutes per week spent in moderate-to vigorous-intensity PA (AM) brisk and general walking (WM) during the past 7 days was assessed using a self-administered modified version of the International Physical Activity Questionnaire (IPAQ).²⁵ Two questions assess days per week and time per session for moderate and vigorous PA lasting 10 minutes or more per session. Three questions assess daily and brisk walking at work, at home, for transportation, and for recreation, sport, exercise, or leisure for 10 minutes or more per session. To increase the accuracy of self-

reported data, the version modified by Whitt-Glover et al was used.²⁵ Whitt-Glover and colleagues modified the questions by changing open-ended questions related to frequency to closed-ended questions.²⁵ Because walking was the activity reported most often in this sample, it was analyzed independent of other PA. Walking minutes were calculated as the total number of minutes of general and brisk walking each week. Walking was categorized as “no activity” (0 walking minutes per week), “some activity” (more than 0 minutes but less than 150 minutes per week), and “150+ minutes per week.” These categories were based on CDC recommendations of 30 minutes of activity per day, most days of the week (5 days).²⁶ Total PA was calculated as the total number of minutes spent in vigorous activity, moderate activity and brisk walking each week. Total PA was categorized as “no activity” (0 activity minutes per week), “some activity” (more than 0 but less than 150 minutes per week) and “150+ minutes.”

Physical Measures—Physical measures included blood pressure, waist circumference, height, and weight. Blood pressure was measured using a Dynamap automated blood pressure device once the participant was seated for at least 5 minutes. Two measures were taken with a 1-minute interval between and the average of the 2 measures recorded. Waist circumference was measured in the recumbent position and directly over the skin.²⁷ A Gulick anthropometric tape measure was placed at the midpoint between the inferior margin of the last rib and the crest of the ilium on both sides. Weight was measured on a digital scale in light indoor clothing and height was measured using a stadiometer with a level bubble and without shoes.

Blood Measures—Phlebotomy was performed by trained, certified phlebotomists following at least an 8 hour fast (typically over night) in accordance with ADA guidelines. Glucose, insulin and lipid profiles were measured in the Clinical Chemistry Laboratory of Wake Forest Baptist Medical Center. The insulin assay used was the paramagnetic particle, chemiluminescent immunoassay for the Access Immunoassay Systems from Beckman Coulter. The overall within assay variability for insulin is 3.9% and the between assay variability is 5.5%. Between assay variability of the human quality control samples was 7.8% at 12 uU insulin-ml and 4.3% at 42.6 uU insulin-ml. Glucose was measured using the timed endpoint method supplied by Beckman Coulter for the Synchron LX Analyzer. This method, developed by the American Association of Clinical Chemistry and Centers for Disease Control, has been accepted as a reference method for glucose determination. Within-run coefficients of variation (CV) for this method are less than or equal to 2% and total CVs are less than or equal to 3%. Triglycerides and HDL cholesterol were measured using a timed endpoint method supplied by Beckman Coulter for the Synchron LX Analyzer.

Statistical Analysis—Descriptive statistics including means and frequency were calculated for the entire population and by MetS status. Due to the skewed distributions of some of the MetS criteria, Spearman correlations were used to assess the relationships between the criteria and activity measures. Generalized Estimating Equation (GEE) models were used to evaluate the association of activity measures with MetS status. There are 4 unadjusted and 4 adjusted models presented in Table 2. Included in the adjusted models were covariates for age, sex, race/ethnicity, and educational attainment. Walking minutes and total PA minutes were both analyzed as continuous measures and categorized as described previously. All analysis were done using SAS version 9.2 (SAS Institute, Cary, NC) statistical package. Results are considered to be statistically significant when $P < .05$.

Results

The recruitment and randomization process with participant yield is represented in Figure 1. From 1818 screenings by phone, a total of 301 individuals were enrolled. Participant characteristics are shown in Table 1. The HELP PD sample was 57.5% female and 27% nonwhite or Hispanic. At baseline, the mean age was 57.9 ± 9.5 years and the mean BMI was 32.7 ± 4 kg·m².

The HELP PD Population

Table 1 represents the baseline characteristics from the HELP PD study by MetS status. MetS groups differed in total walking and general walking minutes ($P = .022$, $.018$, respectively), moderate activity minutes ($P = .041$) and the number reporting no walking or activity ($P = .026$). As expected, MetS groups differed significantly ($P < .001$) in number of MetS components, BMI, waist circumference, fasting glucose, systolic and diastolic blood pressure, HDL cholesterol and triglycerides. Notably, 60% of the study population was identified as having MetS and only 23% of the total sample reported meeting the CDC-recommended level of PA for health benefits (150 AM). Of those with MetS, only 18% reported meeting the AM goal compared with 30% ($P = .021$) of those without MetS. Similarly, only 28% of the sample reached the goal of 150 WM (23% with MetS and 36% without, $P = .016$). The median total walking minutes for the whole sample was 70 minutes and the median moderate activity minutes was 60 minutes. Twenty-four percent of the whole sample reported no walking minutes per week and, separately, 25% reported no activity minutes. In addition, 15% reported both 0 minutes walking and 0 minutes of activity.

Physical Activity and the Presence of the Metabolic Syndrome

The exposure variables for the current study, total walking minutes per week (WM) and moderate activity minutes per week (AM) were moderately correlated ($r = .49$, $P < .0001$). Figure 2 depicts the prevalence of MetS by WM and AM. For both WM and AM, the percentage of individuals with MetS was lower with greater activity. This trend was significant for both WM ($P_{\text{trend}} = .024$) and AM ($P_{\text{trend}} = .041$).

Odds ratios for the presence of MetS associated with walking and moderate activity are presented in Table 2. Continuous measures were used to evaluate the association of a 60-minute-greater level of activity with MetS and categorical measures were used to evaluate the association of reaching activity goals with MetS. In an analysis adjusted for age, sex, race/ethnicity, educational attainment, smoking status and alcohol consumption, the odds of having MetS was 0.15 times ($P = .017$) lower with 60 more walking minutes per week. Evaluating the association between MetS and walking using the categorical measure in an adjusted model, the odds of having MetS was 0.52 times ($P = .046$) lower for participants who met the goal of 150 minutes per week compared with those who reported no activity. Also presented in Table 2 are the associations between MetS and total activity minutes. Using the continuous measure in an adjusted model, the odds of having MetS was 0.15 times ($P = .017$) lower with 60 minutes more per week of moderate activity.

The association of the categorical measure of total activity with MetS in an adjusted model showed individuals meeting the goal of 150 minutes of moderate activity per week had a 0.64 times lower odds of MetS ($P = .009$) compared with those reporting no activity.

Discussion

The purpose of the present report was to describe baseline PA and its relationship to MetS in individuals with prediabetes enrolled in a group behavioral weight loss study. As expected,

in this sample of overweight and obese adults meeting the criteria for prediabetes, there was a much higher prevalence of MetS (60%) than in the US adult population (approx. 33%).¹⁷ Additionally, the number of individuals in this sample (23%) meeting the minimum PA guidelines (150 minutes per week) is far below national averages (43.5%, BRFSS).¹⁵ A higher prevalence of MetS would be expected in this group given the inclusion criteria of overweight/obese and elevated blood glucose. In addition, the current study found that the prevalence of MetS was inversely related to PA such that greater time spent walking and/or engaging in moderate activity was associated with lower odds of MetS. Those persons meeting the minimum of 150 minutes of weekly walking or total moderate PA had the lowest odds of MetS. In addition, in this sample of adults with prediabetes, engaging in an additional hour of walking or moderate activity per week was associated with .15 times lower odds of MetS.

This finding is consistent with the available literature. Churilla reported that MetS was between 39 and 46% less likely in otherwise healthy adults meeting the public health recommendation for PA (30 minutes 5 days per week of moderate activity OR 20 minutes 3 days per week of vigorous activity, determined by NHANES questionnaire).¹⁶ Among apparently healthy Peruvian adults, those who exercised (determined using the Pan American Health Organization questionnaire) some but less than 150 minutes per week had a 21% lower risk of MetS and those who exercised at least 150 minutes per week had a 42% reduction in risk of MetS.²⁸ Differences in the present group compared with these studies can likely be attributed to the difference in populations (healthy adults vs. individuals with prediabetes). Prevalence of MetS in the NHANES sample was 36%, in the Peruvian sample was 27% and in the present sample was 60%.

In the Finnish Diabetes Prevention Study (FDPS), incidence of MetS was positively related to weight gain and inversely related to PA.²⁹ Change over time in PA was also related to change in MetS status. Taken together with the findings of the current study, it appears that meeting at least the minimum recommended amount of activity of 150 minutes per week (in walking or moderate activity) provides a reduced risk of MetS. Walking minutes per week included brisk and general walking, though few participants reported brisk walking. The present sample most often reported walking for physical activity.

The findings presented here must be interpreted in the context of several limitations. Our sample was relatively small and only included individuals with prediabetes and, therefore, these results may not apply directly to nonprediabetic populations. However, previous reports have substantiated this relationship in the more general population of adults,^{16,17,28,30,31} and according to the NIDDK National Diabetes Statistics, from 2003–2006, the estimated prevalence of prediabetes was 25.9%. Thus, the results of the current study have implications for a sizeable portion of the US population. We also used a cross-sectional design and the analyses presented here assume directionality such that physical activity influences MetS. In this design we cannot assume the direction of these relationships. However, it seems unlikely that MetS status would have lead to lower levels of walking and moderate activity. In addition, although our measure of PA (IPAQ) has been validated in diverse samples,³² it is a self-report measure and may be subject to expectation and recall biases. Whereas accelerometers may provide a more objective measurement technology, they are more costly to administer and not generally available to a large proportion of the population. In light of the community-based, translational nature of this project and the moderate agreement observed between accelerometer and questionnaire measurements of PA among adults,^{33,34} self-report measurement was assumed to be a reasonable method for estimating PA in this study. It should also be noted that numerous other studies that have examined the relationship between PA and MetS have relied on self-report measures.

In conclusion, a greater number of walking minutes and total activity minutes per week is associated with a lower risk of MetS. These results support the notion that higher levels of activity may have health benefits even in obese, high-risk populations with evidence of elevated blood glucose. PA may also prevent or reverse MetS in persons who are overweight or obese with prediabetes, in addition to preventing diabetes. Greater time spent walking and/or in moderate activity may reduce the risk of developing MetS in persons with prediabetes as well as reducing the risk of developing diabetes. This is an important public health message as walking is an easy, inexpensive, and well-tolerated activity. Moreover, adding 60 minutes per week of walking, or 10 minutes per day for 6 days per week, is an attainable goal, even for high risk populations. While self-reported PA measures have methodological challenges, these data provide evidence for promoting achievable increases in PA. An additional hour per week of walking or moderate activity may reduce the incidence or prevalence of MetS in overweight and obese individuals who have or are at risk for developing MetS. Those persons who meet or exceed 150 minutes of walking per week and/or meet the CDC recommendation of 150 minutes per week (30 minutes, 5 times per week) spent in moderate activity may obtain an even greater benefit. Future efforts should examine the relationship between changing physical activity level and MetS status over time. In addition, research is needed that focuses on the effectiveness of approaches to promote walking and other forms of moderate activity in this population.

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Figure 1.
Study flow diagram.

Figure 2. Prevalence of Metabolic Syndrome by categories of walking minutes and moderate activity minutes per week in the Healthy Living Partnerships to Prevent Diabetes study population.

Table 1
Descriptive Statistics of the HELP PD Participants by Metabolic Syndrome Status

Characteristic	Mean (SD)	Total population (N = 301)	Metabolic Syndrome (n = 180)	No Metabolic Syndrome (n = 121)	P-value [*]
Age (at randomization)		57.9 (9.5)	57.6 (9.4)	58.4 (9.8)	0.472
Sex					0.914
Male	N (%)	128 (42.5%)	77 (42.8%)	51 (42.1%)	
Female	N (%)	173 (57.5%)	103 (57.2%)	70 (57.9%)	
Race [†]					0.223
White	N (%)	222 (73.8%)	137 (76.1%)	85 (70.2%)	
Non-White	N (%)	78 (25.9%)	42 (23.3%)	36 (29.8%)	
Ethnicity [‡]					0.685
Hispanic	N (%)	4 (1.3%)	2 (1.1%)	2 (1.7%)	
Non-Hispanic	N (%)	295 (98%)	177 (98.3%)	118 (97.5%)	
Race/ethnicity [‡]					0.208
White	N (%)	220 (73.3%)	136 (76.0%)	84 (69.4%)	
Non-White/Hispanic	N (%)	80 (26.7%)	43 (24.0%)	37 (30.6%)	
Educational attainment					0.506
High School or less	N (%)	61 (20.3%)	36 (20%)	25 (20.7%)	
Some college—Bachelors	N (%)	170 (56.5%)	106 (58.9%)	64 (52.9%)	
Grad school or more	N (%)	70 (23.3%)	38 (21.1%)	32 (26.4%)	
Smoking status [‡]					0.356
Current	N (%)	16 (6.1%)	10 (6.5%)	6 (5.6%)	
Former	N (%)	115 (44.1%)	73 (47.4%)	42 (39.3%)	
Never	N (%)	130 (49.8%)	71 (46.1%)	59 (55.1%)	
Alcohol consumption (g)	Median (IQR)	1.0 (8.1)	0.9 (4.9)	1.1 (11.4)	0.213
Total walking minutes	Median (IQR)	70 (140)	60 (135)	90 (160)	0.022
General walking minutes	Median (IQR)	45 (95)	40 (90)	60 (85)	0.018
Brisk walking minutes	Median (IQR)	10 (50)	10 (45)	20 (60)	0.162
No walking	N (%)	71 (23.6%)	47 (26.1%)	24 (19.8%)	0.209
150+ walking minutes	N (%)	84 (27.9%)	41 (22.8%)	43 (35.5%)	0.016
Moderate activity minutes	Median (IQR)	60 (125)	55 (110)	75 (155)	0.041

Characteristic	Total population (N = 301)	Metabolic Syndrome (n = 180)	No Metabolic Syndrome (n = 121)	P-value [*]
No moderate activity	N (%)	48 (26.7%)	26 (21.5%)	0.306
150+ moderate minutes	N (%)	69 (22.9%)	36 (29.8%)	0.021
No walking or moderate activity	N (%)	44 (14.6%)	11 (9.1%)	0.026
Number of Metabolic Syndrome components	Mean (SD)	3.5 (0.6)	1.6 (0.6)	<0.001
BMI (Kg·m ²)	Mean (SD)	32.7 (4)	31.2 (4)	<0.001
Waist circumference (cm)	Mean (SD)	104.7 (10)	100.4 (10.1)	<0.001
Glucose (mg·dL)	Mean (SD)	105.5 (11.3)	101.8 (9.2)	<0.001
Systolic Blood Pressure (mmHG)	Mean (SD)	127.1 (14.1)	121 (12)	<0.001
Diastolic Blood Pressure (mmHG)	Mean (SD)	73.2 (9.3)	70.8 (8.8)	<0.001
HDL (mg·dL)	Mean (SD)	46.4 (12.1)	53.3 (12.2)	<0.001
Triglycerides (mg·dL)	Median (IQR)	119 (80)	91 (61)	<0.001

Abbreviations: HELP PD, Healthy Living Partnerships to Prevent Diabetes.

^{*} Testing the difference between metabolic syndrome groups was done using chi-square tests for frequencies, *t* tests for means, and Kruskal-Wallis test for medians.

[†] Missing values.

Table 2

Odds Ratios and Corresponding 95% Confidence Intervals for the Association of Walking and Moderate Activity With Metabolic Syndrome in the HELP PD Population

	Unadjusted		Adjusted*	
	OR (95% CI)	P	OR (95% CI)	P
Walking minutes (60-minute increment)	0.85 (0.77, 0.95)	0.005	0.85 (0.75, 0.97)	0.017
Walking minutes (categorical)				
Some walking vs No walking	0.87 (0.48, 1.58)	0.647	0.82 (0.42, 1.60)	0.565
150+ walking minutes vs No walking	0.49 (0.25, 0.93)	0.030	0.48 (0.23, 0.99)	0.046
Moderate activity minutes (60-minute increment)	0.87 (0.77, 0.98)	0.020	0.85 (0.74, 0.97)	0.017
Moderate activity minutes (categorical)				
Some activity vs No activity	0.91 (0.51, 1.62)	0.745	0.79 (0.41, 1.51)	0.650
150+ activity minutes vs No activity	0.50 (0.25, 0.97)	0.041	0.36 (0.17, 0.78)	0.009

* Adjusted for age, sex, race/ethnicity, educational attainment, smoking status, and alcohol consumption