Effects of a 12-Month Pedometer-Based Walking Intervention in Women of Low Socioeconomic Status

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ABSTRACT: This study examined the effects of a 12-month walking intervention in overweight/obese, low socioeconomic women. Forty-six women (48.2 ± 8.0 years) entered the study. Outcomes included weight, waist and hip circumferences, body mass index (BMI), blood pressure, glycosylated hemoglobin, blood lipids, fibrinogen, and high-sensitivity C-reactive protein (hsCRP). Both intention-to-treat analyses in all participants and group analyses in study completers only (3K group = increased steps/day by ≥3,000; No Δ group = did not increase steps/day by ≥3,000) were conducted. Group × time ANOVA was used. In study completers, 3K significantly increased steps/day (6,903 ± 3,328 to 12,323 ± 5,736) compared to No Δ (4,926 ± 3,374 to 5,174 ± 3,095) from baseline to 12 months. There was a significant time effect for weight ($P = 0.030$), BMI ($P = 0.029$), and hsCRP ($P = 0.044$). Low socioeconomic women who adhere to a long-term, pedometer-based walking intervention significantly increased steps/day and may improve body weight, BMI, and hsCRP. This could help reduce health disparities in this population over time.

KEYWORDS: low income, overweight, obesity, African-American, cardiometabolic, cardiovascular disease risk

Introduction

Recent data collected in the US have shown that life expectancy increases with income.[1] This raises serious health concerns about individuals living in a chronic state of economic hardship. Recent data have also shown that US adults and children living on low incomes have disproportionately higher rates of obesity, with particular concentration in the southeast region of the US.[2] Specifically, 33% of individual adults earning <$15,000/year and ~25% of those earning >$50,000/year are categorized as obese.[2] Excess body weight and high body mass index (BMI) values have been positively associated with the prevalence of cardiovascular disease, type 2 diabetes, hypertension, dyslipidemia, endogenous inflammation, and a pro-thrombotic state.[3] As obesity persists as a critical health concern and major contributor to poor health outcomes in the US, investigators continue to study ways to combat the obesity epidemic.

It is well established that regular physical activity (PA) is associated with low body weight and fat mass, and assists with the maintenance of ideal weight.[4] Research has shown that few overweight and obese individuals adhere to structured exercise programs in the long term.[5–7] One alternative to structured exercise programs is small increases in accumulated daily PA through low-intensity walking and activities of daily living.[8] Further, research has shown that these activities performed at a comparable total volume generate similar health benefits as higher intensity, structured exercise.[9–12] PA monitoring using pedometers provides instant feedback and motivation, and interventions using pedometers have been shown to be beneficial in increasing daily PA and improving cardiometabolic health outcomes in interventions conducted in the free-living environment with overweight/obese participants.[13,14] Previous research examining pedometer-determined PA in a group of men and women residing in low-income housing showed significantly lower PA levels in women compared to men and in overweight/obese individuals compared to those who were normal weight.[15] These associations highlight the fact that overweight and obese women of low socioeconomic status are a particularly vulnerable group in terms of susceptibility of

exposure to a combination of social, environmental, behavioral, and physiological risk factors that contribute to obesity and its related comorbidities. Further, women of low socioeconomic status are a population that is understudied in regard to their health-related needs.

To our knowledge, only one study has examined pedometer-based PA interventions in a sample of women of low socioeconomic status.[16] The intervention group in that study was overweight and obese; however, the duration of the intervention was 24 weeks, and only changes in body weight, percentage of body fat, and waist circumference were reported. Therefore, the purpose of this study was to evaluate the effects of a long-term (12-month), pedometer-based walking intervention on average steps/day and multiple variables related to cardiometabolic risk in overweight and obese women of low socioeconomic status. Outcome measures included body weight, BMI, waist and hip circumferences, blood pressure, total cholesterol, high-density lipoprotein cholesterol (HDL-C), triglycerides, glycosylated hemoglobin (HbA1c), high-sensitivity C-reactive protein (hsCRP), and fibrinogen. These were selected based on their established relationship to obesity and cardiometabolic health, as well as the current lack of information on the effects of walking on these variables in women of low socioeconomic status in the southeastern region of the US. We hypothesized that women who achieved an increase in daily walking by $\geq$3,000 steps/day over 12 months would decrease their body weight and show improvements in each of the outcome measures. The delineation of 3,000 steps was chosen based on the intent to measure the effects of modest changes over the year.

Methods

Overweight and obese women on Medicaid, 30–65 years of age, and living in Tallahassee, FL, and Quincy, FL, were recruited to participate in this exercise intervention study. Study recruitment took place over 6 months, which extended the complete study length to 18 months. Recruitment strategies included hanging flyers and personal contact with potential participants at multiple venues that serviced the target population including churches, community clinics/health departments, and various government assistance offices (welfare, Department of Children and Families, Florida Food Stamps, Special Supplemental Nutrition Program for Women, Infants, and Children, etc). Participants were excluded from the study if they were currently in an exercise program, had any orthopedic limitations that interfered with their ability to walk with ease, had BMI values <25.0 kg/m^2, and/or were not on Medicaid. In an effort to maximize community outreach in this population, there was no exclusion criteria based on baseline steps/day. Approval of the study was obtained from the Florida State University Institutional Review Board, and all participants completed an approved informed consent form prior to participation. The research in this study complied with the principles of the Declaration of Helsinki.

Testing was completed in groups, in the morning following a 12-hour fast, at five designated sites that included community centers and apartment complex activity rooms. Participants were also asked to refrain from smoking and using tobacco for at least 30 minutes prior to measurements. Participants reported, or were transported by study staff, to one of the five testing sites that was nearest to their residence. This was consistent across participants, except for rare occasions when a participant missed the onsite testing day and agreed to undergo testing at the Florida State University Exercise Physiology Laboratory. Participants first completed questionnaires on demographic and health histories. Next, resting blood pressure was taken in duplicate after the participants had been seated for at least five minutes. Standard guidelines described by the American Heart Association were used.[17] Body height without shoes was measured using a wall-mounted tape measure, and body weight in indoor clothing without shoes was measured with a portable scale. Measured height and weight were used to calculate BMI in kg/m^2. Waist circumference was measured at the smallest area around the torso, above the umbilicus and below the xiphoid process. Hip circumference was measured at the widest area of the buttocks with feet together. Both were measured with a measuring tape per guidelines outlined by the American College of Sports Medicine.[18]

Blood samples were obtained on site by a study investigator trained in phlebotomy, using standard venipuncture procedures and sanitation practices. Whole blood was transported on ice to the Florida State University Exercise Physiology Laboratory for immediate processing, storage, and analysis. Analyses were conducted immediately on EDTA-treated whole blood for HbA1c. For the remaining blood variables, whole blood was centrifuged for 20 minutes at 2,800 rpm, and aliquots of plasma or serum were stored at –20°C for further analysis.[19–23] Sodium citrate-treated plasma was used for fibrinogen, and serum was used for total cholesterol, HDL-C, triglycerides, and hsCRP. Procedures by Warnick et al[24,25] and Gidez et al[26] were used to precipitate HDL-C with internal controls. Cholesterol and triglycerides were quantified using colorimetric reagents and standards. Fibrinogen was determined using a fibrometer coagulation analyzer and hsCRP protein using an ELISA kit. Blood variables were measured in duplicate, except HbA1c which was measured only once. The coefficient of variations was 2.2% for total cholesterol, 2.1% for HDL-C, 2.5% for triglycerides, 1.7% for fibrinogen, and 14.4% for hsCRP.

At the end of their testing visit, participants were given a Yamax Digiwalker SW-701 pedometer (New Lifestyles, Inc.) and a log book to record daily steps. This pedometer was chosen based on the accuracy reported in previous validation studies[27,28] and its use with overweight and obese adults.[13,14] Pedometers were placed on the waistband and aligned with the middle of the knee cap. Participants were instructed to put the pedometers on in the same location and record the

time when they woke in the morning and to only remove them when sleeping, bathing, or swimming. Participants were also instructed to remove the pedometer before retiring each evening, record the time and total number of steps taken that day into their log book, and reset the pedometer back to zero for the next day. The first two weeks of the study were used to establish a baseline of steps/day. Study staff then made weekly telephone calls to participants for the first six months of the intervention to answer any study-related questions and obtain the number of steps recorded for each day of that week. On the call, participants were also asked to increase their number of daily steps by 5%–10% of what they averaged the week before, depending upon baseline steps/day and reported feasibility (ie, access to or ability to travel to a safe walking environment). Step goals were given in steps/day. After six months, participants were contacted every two weeks to encourage maintenance of their steps/day and to report step-count data.

Every three months, the participants reported back to their respective testing site and were re-evaluated on each of the measurements described above. At the completion of each three-month period, pedometer log books were collected and checked by investigators to confirm the steps/day that were obtained over the telephone. Participants were paid $125 cash to participate in the study, which included $10 at baseline, 3, 6, and 9 months and $85 at 12 months. This amount was chosen in an effort to prevent attrition, yet avoid the likelihood of coercion.

Participants were not excluded from the study based on baseline steps/day. Investigators made this ethical decision as they considered these women vulnerable in terms of potential for poor health outcomes (overweight/obese, low income and low access to health resources, low education levels, understudied in the literature, difficult to reach for health care follow-up). As such, changes across 12 months were measured in relative terms based upon the average step/day increase achieved during the intervention. Participants were first analyzed as one group, which included all who entered the study. Then participants who completed the study were delineated into two groups for a separate analysis. The groups included those who did not comply with the guided recommendations to gradually increase their steps/day (No Δ) and those who improved average steps/day by ≥3,000 (3K). This delineation was chosen based on the intent to measure the effects of modest changes over the year, with an annual 3,000 step/day increase equating to a 250 step/day increase each month. Further, previous studies have shown significant improvements in body composition and multiple cardiometabolic risk factors with step/day increases from 2,472 to 4,241 steps/day above baseline.[13,14]

One-way analysis of variance was used to examine the differences between intervention completers and non-completers at baseline, and to compare the No Δ and 3K groups at baseline. Chi-square tests were used to examine differences in categorical data in intervention completers and non-completers at baseline. Intention-to-treat analyses were conducted for all participants, where missing data points were filled using data collected closest to the time of study dropout. These analyses evaluated the effect of average steps/day on the dependent variables by two-way (group × time; 2 × 5) analysis of variance with repeated measures on the last factor. Pairwise comparisons with Bonferroni adjustments were used to inspect significant findings.

The effect of average steps/day on the dependent variables were analyzed in intervention completers only by two-way (group × time; 2 × 5) ANOVA with repeated measures on the last factor. If there were significant interactions, simple contrasts were used to determine the significance between the two groups and among the different time points. Pearson product moment correlations were used to evaluate the relationships between the changes in baseline and 12-month data between steps/day and measured cardiometabolic risk variables for the No Δ and 3K groups combined. Statistical analyses were completed using IBM SPSS statistical analysis software version 22 (IBM Corporation). Values are presented as mean ± standard deviation. Significance was accepted at $P < 0.05$.

Results

Figure 1 illustrates the progression of participants through the study. Sixty-two women contacted study staff to participate and were screened for eligibility. Sixteen women were excluded (13 were not on Medicaid, one was in a wheel chair, and two were not mentally competent to follow study protocol). Of the 46 women who entered the study, all were on Medicaid at enrollment and for the duration of the study. A total of 83% of participants were African-American, 13% were Caucasian, and 4% were Hispanic.

Baseline participant characteristics are presented in Table 1. On average, these women had a high school education. Participants had an average of four concurrent diagnosed medical conditions including hypertension (59%), type 2 diabetes (35%), and high cholesterol (24%). As such, participants were taking an average of four medications for management of these chronic diseases. In addition, 35% were taking antidepressants or some form of psychotropic medication. None of the participants were taking medication for birth control, and only two participants were on hormonal replacement therapy. A total of 31% of participants smoked or chewed tobacco. Of the 46 women who entered the study, 29 completed the study (37% dropout). Participants were eliminated from analyses if they failed to report step data at each of the time points over the 12 months.

Table 2 shows the results from the intention-to-treat analyses of all participants who entered the intervention and reported step data ($n = 41$). The data show a significant increase in steps/day over 12 months ($P < 0.01$). Pairwise comparisons with Bonferroni adjustment showed a significant increase in average steps/day from baseline to 3 months ($P < 0.01$), which remained throughout the intervention (6 months: $P < 0.01$, 9 months: $P = 0.01$; 12 months: $P = 0.01$). No other significant
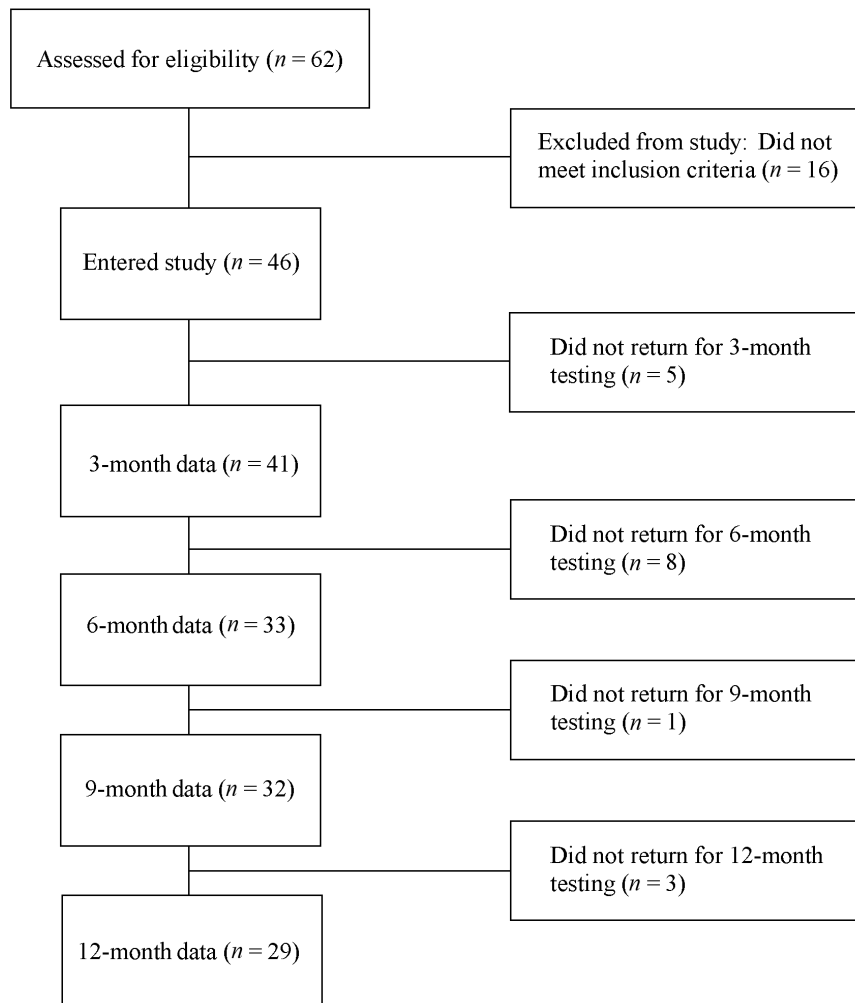
Figure 1. Progression of participants through the study.

changes were observed for variables in the intention-to-treat analyses of all participants.

Table 3 presents data across 12 months for the participants who completed the study and reported step data ($n = 26$). The 3K group had significantly higher triglycerides at baseline compared to the No Δ group (215 vs 121 mg/dL; $P = 0.047$). There were no other significant differences between the 3K and No Δ groups at baseline. There was a significant group × time interaction for steps/day ($F_{4,21} = 10.604$; $P < 0.001$; effect size (ES) = 0.669). Separate repeated measures ANOVAs showed a significant time effect for average steps/day in the 3K group ($F_{4,3} = 12.934$; $P = 0.031$; ES = 0.945), while the No Δ group had no significant time effect ($F_{4,15} = 1.458$; $P = 0.264$; ES = 0.280). Simple contrasts comparing each time point to baseline in the 3K group showed significant changes at 6 ($P < 0.001$), 9 ($P = 0.004$), and 12 months ($P = 0.003$).

Although no other significant interactions were observed, there was a significant time effect for weight ($F_{4,21} = 3.295$; $P = 0.030$; ES = 0.386), BMI ($F_{4,21} = 3.322$; $P = 0.029$; ES = 0.388), and hsCRP ($F_{4,17} = 3.091$; $P = 0.044$; ES = 0.421). Simple contrasts showed significant changes for weight at 6 (107.2 ± 27.3 kg; $P = 0.028$), 9 (106.3 ± 26.1 kg; $P = 0.004$), and 12 (107.0 ± 26.6 kg; $P = 0.011$) months when compared to baseline (108.4 ± 26.3 kg), significant changes for BMI at 6 (40.1 ± 9.6 kg/m^2; $P = 0.024$), 9 (39.8 ± 9.1 kg/m^2; $P = 0.004$), 12 (40.1 ± 9.4 kg/m^2; $P = 0.009$) months when compared to baseline (40.6 ± 9.3 kg/m^2), and significant changes for hsCRP at 3 (19 ± 18 mg/L; $P = 0.015$) and 12 months (17 ± 17 mg/L; $P = 0.007$) when compared to baseline (22 ± 21 mg/L). There was a significant negative correlation between the change (baseline to 12 months) in steps/day and hsCRP ($r = -0.497$; $P = 0.019$), where steps/day increased as hsCRP decreased over time. There was a marginally significant negative correlation between changes (baseline to 12 months) in average steps/day and the change BMI ($r = -0.389$; $P = 0.050$), where steps/day increased as BMI decreased over time. There were no other significant correlations between steps/day and any other variable.

Discussion

This intervention was successful in significantly improving steps/day in women of low socioeconomic status. To our knowledge, this is only the second intervention study that

Table 1. Baseline descriptive characteristics of participants ($n = 46$).

VARIABLES	ALL ($n = 46$)	NON-COMPLETERS ($n = 17$)	COMPLETERS ($n = 29$)
Age (years)	48.2 ± 8.0	48.1 ± 7.8	48.3 ± 8.1
Baseline steps (steps/day)	4916 ± 2977 ($n = 41$)	3977 ± 1735 ($n = 15$)	5458 ± 3414 ($n = 26$)
Height (m)	1.62 ± 0.06	1.61 ± 0.06	1.63 ± 0.06
Body weight (kg)	106.7 ± 26.5	100.3 ± 24.2	110.4 ± 27.5
Body mass index (kg/m^2)	40.5 ± 9.8	39.1 ± 10.0	41.3 ± 9.8
Waist (cm)	111 ± 17	108 ± 17	112 ± 17
Hip (cm)	130 ± 19	125 ± 16	132 ± 20
Systolic BP (mmHg)	128 ± 18	125 ± 18	130 ± 19
Diastolic BP (mmHg)	79 ± 9	76 ± 11	81 ± 8
HbA1c (%)	6.1 ± 1.3 ($n = 40$)	6.1 ± 1.4 ($n = 14$)	6.1 ± 1.2 ($n = 26$)
Triglycerides (mg/dL)	124 ± 87 ($n = 42$)	100 ± 35 ($n = 16$)	138 ± 105 ($n = 26$)
Total cholesterol (mg/dL)	202 ± 42 ($n = 42$)	198 ± 34 ($n = 16$)	204 ± 47 ($n = 26$)
HDL-C (mg/dL)	50 ± 17 ($n = 42$)	50 ± 17 ($n = 16$)	50 ± 17 ($n = 26$)
Fibrinogen (mg/dL)	466 ± 115 ($n = 40$)	487 ± 165 ($n = 14$)	455 ± 77 ($n = 26$)
hsCRP (mg/L)	19.9 ± 20.7 ($n = 42$)	17.2 ± 20.8 ($n = 16$)	21.6 ± 20.8 ($n = 26$)
Education (years)	12.3 ± 2.0 ($n = 45$)	12.4 ± 2.9 ($n = 16$)	12.3 ± 1.4 ($n = 29$)
Medications (#)	3.9 ± 3.4	3.1 ± 2.7	4.3 ± 3.7
Diseases (#)	4.5 ± 2.6	3.4 ± 2.3	5.1 ± 2.6*
Smoking (#)$^\chi$	Nonsmokers: 31	Nonsmokers: 11	Nonsmokers: 20
	Smokers: 14	Smokers: 6	Smokers: 8
	($n = 45$)	($n = 17$)	($n = 28$)
Race/ethnicity$^\chi$	African-American: 38	African-American: 15	African-American: 23
	Caucasian: 6	Caucasian: 1	Caucasian: 5
	Hispanic: 2	Hispanic: 1	Hispanic: 1

Notes: Values presented as mean ± SD. Number of participants is included for variables with missing data. *Significantly different from non-completers group at baseline ($P < 0.05$). Chi-square analysis for categorical data. Baseline steps were taken over at two-week period at the beginning of the study.
Abbreviations: Waist, waist circumference; hip, hip circumference; BP, blood pressure; HbA1c, glycosylated hemoglobin; HDL-C, high-density lipoprotein cholesterol; hsCRP, high-sensitivity C-reactive protein.

Table 2. Intention-to-treat analyses of body composition and cardiovascular risk factors for all participants over 12-months ($n = 41$).

VARIABLES	BASELINE	3-MONTH	6-MONTH	9-MONTH	12-MONTH
Steps/day*	4916 ± 2977	6244 ± 4679$^\psi$	6174 ± 3687$^\psi$	61995 ± 3973$^\psi$	6317 ± 4354$^\psi$
Body weight (kg)	105.9 ± 26.0	105.9 ± 26.5	105.1 ± 26.8	104.9 ± 26.4	104.9 ± 26.4
Body mass index (kg/m^2)	40.2 ± 9.6	40.3 ± 9.9	39.9 ± 10.0	39.7 ± 9.7	39.9 ± 9.8
Waist (cm)	110 ± 17	110 ± 18	109 ± 18	110 ± 18	111 ± 18
Hip (cm)	129 ± 18	130 ± 19	130 ± 19	130 ± 19	130 ± 19
Systolic BP (mmHg)	128 ± 19	125 ± 20	125 ± 18	126 ± 17	126 ± 19
Diastolic BP (mmHg)	79 ± 10	78 ± 10	77 ± 10	78 ± 10	78 ± 12
HbA1c (%) ($n = 35$)	6.2 ± 1.3	6.3 ± 1.5	6.1 ± 1.3	6.2 ± 1.3	6.3 ± 1.3
Triglycerides (mg/dL) ($n = 37$)	131 ± 89	130 ± 105	138 ± 97	122 ± 60	120 ± 58
Total cholesterol (mg/dL) ($n = 37$)	203 ± 43	201 ± 47	203 ± 46	194 ± 39	192 ± 42
HDL-C (mg/dL) ($n = 37$)	50 ± 17	49 ± 15	50 ± 15	49 ± 14	49 ± 13
Fibrinogen (mg/dL) ($n = 34$)	457 ± 113	459 ± 104	447 ± 135	465 ± 96	473 ± 75
hsCRP (mg/L) ($n = 36$)	21 ± 21	19 ± 21	21 ± 21	22 ± 22	18 ± 20

Notes: Values presented as mean ± SD. Number of participants is included for variables with missing data. Five participants were eliminated from analyses due to failure to report step data at any time point. *Significant difference over 12 months ($P < 0.01$). $^\psi$Significantly different from baseline ($P < 0.01$).
Abbreviations: Waist, waist circumference; hip, hip circumference; BP, blood pressure; HbA1c, glycosylated hemoglobin; HDL-C, high-density lipoprotein cholesterol; hsCRP, high-sensitivity C-reactive protein.

Table 3. Comparison of body composition and cardiovascular risk factors for intervention completers over 12-months ($n = 26$).

VARIABLES	BASELINE	3-MONTH	6-MONTH	9-MONTH	12-MONTH
Steps/day**					
3K ($n = 7$)	6903 ± 3328	10,786 ± 7269	11,185 ± 3716$^\Psi$	11,465 ± 4798$^\Psi$	12,323 ± 5736$^\Psi$
No Δ ($n = 19$)	4926 ± 3374	5739 ± 4010	5326 ± 3009	5237 ± 3119	5174 ± 3095
Body weight (kg)*					
3K ($n = 7$)	98.2 ± 17.7	97.3 ± 15.8	94.2 ± 16.1	94.1 ± 16.2	93.8 ± 14.1
No Δ ($n = 19$)	112.2 ± 28.3	112.9 ± 29.0	112.0 ± 29.3	110.9 ± 27.9	111.9 ± 28.7
Body mass index (kg/m^2)*					
3K ($n = 7$)	37.3 ± 7.0	36.9 ± 7.0	35.7 ± 6.0	35.6 ± 6.3	35.5 ± 5.5
No Δ ($n = 19$)	41.8 ± 9.9	42.1 ± 10.2	41.8 ± 10.3	41.3 ± 9.7	41.7 ± 10.1
Waist (cm)					
3K ($n = 7$)	106 ± 14	104 ± 12	104 ± 11	104 ± 12	105 ± 13
No Δ ($n = 19$)	113 ± 17	113 ± 18	112 ± 19	113 ± 18	115 ± 18
Hip (cm)					
3K ($n = 7$)	122 ± 12	121 ± 14	122 ± 16	122 ± 15	121 ± 14
No Δ ($n = 19$)	134 ± 19	136 ± 21	134 ± 22	135 ± 20	136 ± 21
Systolic BP (mmHg)					
3K ($n = 7$)	122 ± 15	117 ± 15	122 ± 23	122 ± 16	119 ± 19
No Δ ($n = 19$)	133 ± 20	130 ± 24	128 ± 17	129 ± 18	131 ± 20
Diastolic BP (mmHg)					
3K ($n = 7$)	78 ± 9	76 ± 10	77 ± 9	78 ± 9	76 ± 7
No Δ ($n = 19$)	82 ± 8	80 ± 11	78 ± 10	78 ± 11	79 ± 14
HbA1c (%)					
3K ($n = 7$)	5.7 ± 0.9	6.2 ± 1.4	6.0 ± 1.2	6.0 ± 0.9	5.9 ± 1.0
No Δ ($n = 16$)	6.3 ± 1.3	6.8 ±1.8	6.4 ± 1.4	6.5 ± 1.4	6.7 ± 1.3
Triglycerides (mg/dL)^					
3K ($n = 7$)	215 ± 161	237 ± 205	236 ± 174	164 ± 86	156 ± 73
No Δ ($n = 16$)	121 ± 58	103 ± 38	120 ± 55	115 ± 52	115 ± 57
Total cholesterol (mg/dL)					
3K ($n = 7$)	226 ± 33	226 ± 48	232 ± 31	214 ± 38	191 ± 45
No Δ ($n = 16$)	198 ± 51	194 ± 52	196 ± 53	182 ± 38	189 ± 46
HDL-C (mg/dL)					
3K ($n = 7$)	52 ± 29	44 ± 11	47 ± 14	47 ± 16	43 ± 10
No Δ ($n = 16$)	46 ± 7	45 ± 11	47 ± 12	45 ± 9	46 ± 10
Fibrinogen (mg/dL)					
3K ($n = 7$)	429 ± 56	448 ± 82	491 ± 121	506 ± 67	479 ± 10
No Δ ($n = 15$)	465 ± 82	454 ± 110	412 ± 145	446 ± 75	478 ± 10
hsCRP (mg/L)*					
3K ($n = 7$)	29 ± 17	13 ± 8	17 ± 12	17 ± 11	10 ± 6
No Δ ($n = 15$)	19 ± 23	21 ± 21	23 ± 21	25 ± 23	19 ± 20

Notes: Values presented as mean ± SD. Three participants were eliminated from analyses due to failure to report step data at any time point. *Significant time effect ($P < 0.05$). **Significant interaction between groups ($P < 0.05$). $^\Psi$Significantly different from baseline ($P < 0.05$). ^Significant difference between 3K and No Δ groups at baseline.
Abbreviations: 3K, increased steps from baseline by ≥3,000 steps/day; No Δ, did not increase steps by ≥3,000 steps/day; waist, waist circumference; hip, hip circumference; BP, blood pressure; HbA1c, glycosylated hemoglobin; HDL-C, high-density lipoprotein cholesterol; hsCRP, high-sensitivity C-reactive protein.

examined pedometer-measured PA in a group of overweight and obese women, all of low socioeconomic status. Clarke et al[16] previously conducted an 8-week educational intervention in 124 low-income, overweight, and obese women (≥ 25 kg/m^2) that used pedometers to track PA changes. Ninety-three participants completed the study (25% dropout), and attendance at the weekly educational sessions averaged 74%. Similar to the participants in the current study, these women significantly ($P < 0.05$) increased PA (from 5,969 to 9,755 steps/day) when compared to controls. In addition, these participants significantly decreased body weight (from 92.7 to 89.8 kg), waist circumference (from 107.4 to 103.9 cm), and percentage of body fat (from 43.0% to 41.6%). Factors that may have contributed to participant motivation and the PA improvement that was observed in this relatively large number of participants were the younger participants (mean age 27 years) compared to the participants of the current study, an intervention that was shorter in duration and one that included more frequent contact with participants through the weekly educational component. Further, the educational component could have increased their study's appeal, as it provided social interaction among participants. Even with payment, we found it difficult to motivate participants to maintain participation and, more importantly, to increase their steps/day over time. Even so, the current results in the 3K group appear similar to those of studies that have shown reductions in body weight and BMI with pedometer intervention programs.[13,29–31] The 3K group showed a significant time effect for body weight and BMI, indicating that both variables changed over the 12-month intervention. However, to minimize type I error, no further statistical analyses were conducted to identify specific groups and/or points at which the significance was detected. As such, we can only report that the 3K group may differ from the No Δ group when considering changes in these variables from baseline to 12 months.

The current study measured the pro-inflammatory marker hsCRP, as chronic inflammation is recognized as a key contributor to atherosclerosis.[32] A significant time effect was discovered over the 12 months. Again, to minimize type I error, no statistical analyses were conducted to further investigate the groups and/or points at which the significance was detected. However, visual inspection of the data showed that by month 3, the 3K group had a large decrease in hsCRP, which remained lower than baseline throughout the study. The change in steps/day from baseline to 12 months and the change in hsCRP had the strongest significant correlation of any of the other cardiometabolic risk factor variables measured ($r = -0.497$). The present study's findings appear consistent with those of previous studies showing that greater amounts of PA corresponded to lower levels of hsCRP.[33,34] It has been shown that socioeconomic status may also have a direct effect on hsCRP. Alley et al[32] showed that the prevalence of very high levels of hsCRP (>10.0 mg/L) was significantly higher

among individuals with family incomes at or below poverty level compared to those living above the poverty level, that African-American women have higher levels of hsCRP compared to other races/ethnicities, and that obesity was the largest risk factor for every level of hsCRP. Their results suggest that very high hsCRP may be due to factors beyond acute illness and could be the result of chronic health, behavioral, and disease processes associated with low socioeconomic status. This may help explain the very high levels of hsCRP among the participants in the present study.

Fibrinogen was measured as a pro-thrombotic biomarker, and both groups had baseline levels well above normal limits (≥ 350 mg/dL).[35] Although it has been shown that fibrinogen is significantly lower in those who are more physically active compared to sedentary individuals,[34] the present study showed no significant changes in fibrinogen overall or when completers were divided into groups. The trend actually showed an increase in fibrinogen in both groups. Our laboratory had previously shown similar results in a population of obese, middle-aged African-American women who participated in a pedometer-based walking intervention, where two intervention groups were asked to gradually increase their daily walking over 12 weeks.[36] Both groups had elevated fibrinogen at baseline, and both showed post-intervention increases in fibrinogen, with a significant increase measured in the group that participated in walking plus resistance training. As we are only able to speculate reasons for the fibrinogen increases in both studies, this is an area that needs to be examined further while closely monitoring and experimenting with suspected reasons for fibrinogen variability including dietary influence, the timing of blood draws in relation to exercise, exercise modality, and exercise intensity.

We did not find any changes in blood pressure or HbA1c in the overall sample or in the 3K group. These results are in contrast to those of Swartz et al,[14] who studied overweight and obese women and found significant reductions in both systolic and diastolic blood pressure, and improved glucose tolerance after only eight weeks of walking.[14] The present study's lack of significant change in blood pressure in the 3K group could be due to the women having near-normal values at baseline (systolic = 122 mmHg; diastolic = 78 mmHg). However, the overall sample and both groups of completers in the present study were categorized as prediabetic at baseline (per the American Diabetes Association's recommendations of 5.7%–6.4%),[37] and no changes in HbA1c were observed. Dietary intake could potentially explain this, but as diet was not measured in the current study, we are unable to examine this further.

There were also no overall changes or group interactions in study completers for any of the blood lipids measured. Triglycerides in the overall sample were within normal limits. For the 3K group, triglycerides were significantly higher at baseline and were higher than normal limits compared to the No Δ group. Even so, the 3K group showed no significant changes

in triglycerides over the intervention, even though a relatively large (from 215 ± 161 to 156 ± 73 mg/dL) non-statistically significant decrease was observed in this group. This differs from the findings by Durstine et al,[38] which suggest triglycerides usually decrease with exercise and greater reductions are often seen in participants who were previously inactive and have higher baseline concentrations, similar to the participants in the present study. Similar to triglycerides, average cholesterol in the 3K group was higher than normal limits at baseline and decreased over the intervention (from 226 ± 33 to 191 ± 45 mg/dL), but did not achieve significance. Cross-sectional and longitudinal exercise studies support these findings, showing that unless exercise is accompanied by substantial weight loss, body composition changes (especially loss of intra-abdominal adiposity), and/or dietary changes, total cholesterol typically does not change.[38] Even without statistical significance, we do feel that the triglyceride and total cholesterol changes observed in the 3K group suggest that a modest increase in 3K should be studied further in a larger sample. HDL-C has been shown to increase in response to exercise and in a dose–dependent manner.[38] However, in the present study there were no significant changes in HDL-C. It has been suggested that exercise needs to be of sufficient intensity to produce changes in HDL-C[38] and that obesity may also blunt the exercise response of HDL-C.[39]

A key strength and novelty of the current study was our ability to obtain both objective measures of PA and a comprehensive cardiometabolic profile in this understudied demographic group. Further, many of the risk factors measured have never been examined after a pedometer-based PA intervention in this population, and certainly not at multiple time points. This study also provides valuable information that will inform future PA intervention work in this hard-to-reach population, and does so through the following challenges and limitations that were endured.

Seventy-three percent (19 of 26) of the women who remained in the study and recorded PA did not adhere to the recommendations to increase steps/day that occurred over 12 months. Communication barriers between study staff and the participants could have been a key contributor to the low intervention adherence. As the study design called for regular telephone contact with the participants to encourage step increases and provide motivation, women who had irregular access to a telephone were difficult to reach. This occurred partly due to income irregularities interrupting telephone service; however, other factors may explain differences in the extent to which these low-income women were able to increase daily steps. Interviews with participants who completed the program suggest that unsafe residential environments with respect to crime and traffic were a concern. Additionally, a lack of sidewalks, lack of social support, health problems, and emotional and mental disorders were among the constraints the women encountered.[40] Further, the above-mentioned factors could clarify why PA may not have been perceived as an immediate priority in this population. Monitoring with the pedometers was also uniquely challenging in these women. Maintaining possession of the pedometers proved difficult for some participants for multiple reasons including loss, damage, theft, and one reported case of selling the pedometer for additional income. Also, despite the study staff's efforts to provide clear instructions on pedometer use, some participants appeared to have difficulty with the technicality of using the pedometer, as well as the concept of recording steps daily. The combination of all of the above-mentioned factors likely had a negative impact on PA and general study procedure compliance, making the acquisition of data complex compared to participants in a higher socioeconomic status category.

As research in women from low socioeconomic status is limited, we felt warranted in an ethical decision to apply the treatment to the entire sample and not assign any of our participants to a control group. Further, we did not exclude anyone from the intervention based on PA at baseline. Despite the thought that was put into choosing an appropriate monetary compensation for the participants (enough to prevent attrition, but not so much that it was the only reason they would participate), these women did appear to be largely motivated to continue the study by the cash incentives that were given for their attendance and participation in the data collection visits. Investigators even encountered occasional requests for advances on incentive money. This is not particularly surprising given the known economic hardships of the population; however, this may help explain why so many women remained in the study yet did not increase their steps/day. The cash incentives did not appear to influence the participants to walk more, based on the fact that many more women remained in the study with no PA changes (*n* = 19) versus those who remained in the study and increased steps/day by ≥3,000 (*n* = 7). Further, three additional participants remained in the study but did not report step data for any time point. We also note that no data were collected on the participants' stage of change using the Transtheoretical Model of Behavior Change. This could have provided valuable information regarding the participants' readiness to adopt additional PA into their lifestyles, which may have influenced motivation and study attrition.

We also recognize that, on average, the women who entered this study were extremely obese (BMI = 40.5 ± 9.8 kg/m²; class III/morbid obesity). Although there was no significant difference in the baseline BMI of participants in the 3K and No Δ groups ($P = 0.278$), the 3K group showed a trend of lower BMI (37.3 ± 7.0 kg/m²) versus the No Δ group (41.8 ± 9.9 kg/m²). As such, we speculate that higher BMI may have negatively influenced intervention adherence. It has been reported that overweight women have higher levels of perceived exertion and displeasure in exercise programs compared to normal weight women.[6] It has also been shown that walking, even at low levels, may be exhausting and uncomfortable for women who are obese and sedentary.[41] We feel that

this does not eliminate the necessity of PA in morbidly obese individuals, but future research may consider the benefit of dietary intervention for weight reduction at some point prior to intervening on PA. This could assist in making PA more comfortable and perhaps more desirable in this group. Non-weight-bearing PA such as stationary cycling, arm ergometry, rowing, or resistance training may also be explored as introductory exercise modalities for extremely obese individuals. However, these exercise modalities are likely less feasible for individuals of low socioeconomic status.

We attribute the inability to detect significant changes in more variables to the small sample size and high variability. Further, the fact that many participants did not comply with the program, even though they remained in the study, likely had a negative impact on our ability to detect significant changes. Even when intention-to-treat analyses were performed with all participants in one group, the results observed were similar to those found when only intervention completers were examined in two groups (3K and No Δ). This study did not measure diet at any time point, but study staff did encourage participants not to change their diet throughout the entire 12 months. Study staff also reminded the participants to remain compliant with their current medications throughout the intervention. Even so, it is recognized that various circumstances reported in this free-living research setting (financial fluctuation, transportation, personal/family issues, self-identified depression, and incarceration) may have prevented consistency in lifestyle over the 12-month study period. These inconsistencies could have impacted diet and medication compliance (and therefore weight and/or some cardiometabolic biomarkers) and could have prevented some participants from walking. Despite these challenges and limitations, we feel that this study is a significant addition to the body of knowledge surrounding PA and health in this underrepresented population.

In conclusion, these data indicate that a 12-month pedometer-based intervention was effective in significantly increasing average steps/day (by 3 months) and the changes were maintained over 12 months. Further, increasing daily walking by at least 3,000 steps/day may have positive effects on body weight, BMI, and hsCRP, which were maintained over 12 months in overweight and obese women of lower socioeconomic status. Each of these factors (weight, BMI, and hsCRP) is critical to obesity-related comorbidities and, if improved, can decrease disparities in these comorbidities in overweight and obese women of low socioeconomic status. Although this population can be challenging to study and motivate, our data show that increasing PA, even by modest amounts, can elicit a positive impact on obesity-related comorbidities over time. Future research in this population should explore strategies for maintaining consistent, long-term communication with low-income participants in an effort to more effectively study the impact of PA on body weight and cardiometabolic risk in these individuals. Attempting more in-person interaction may create more accountability and motivation for the study participants, which could improve study adherence and potentially PA adherence.

Author Contributions

Conceived and designed the experiments: LBP, TT, RJM, EMH, and RM. Collected data: LBP, TT, JDK, MRK, RJM, EMH, and RM. Analyzed data: LMH, LBP, TT, MRK, and JDK. Wrote the first draft of the manuscript: LMH and LBP. Contributed to the writing of the manuscript: LMH and LBP. All the authors jointly developed the structure and arguments for the paper and made critical revisions to the manuscript. All the authors agreed with manuscript results and conclusions. All the authors reviewed and approved the final manuscript.

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