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Barriers to physical activity as moderators of intervention effects

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ABSTRACT

The impact of interventions to increase physical activity (PA) may vary as a function of participants' barriers to PA. The aim of this paper is to determine whether individual barriers (demographic, physical health, psychological health, neighborhood factors, perceived barriers to PA, social support for PA) moderate treatment effects on increases in PA. Three treatment conditions tested the relative efficacy of a group-based PA intervention alone or supplemented by either personal or automated phone calls made between group meetings. From 2010 to 2012, 284 African American women (ages 40–65) living in the Chicago, IL, area were randomized to one of the three treatment conditions. Data collection occurred at baseline as well as 24 and 48 weeks after baseline. Moderation of intervention effects by barriers to PA were tested across four outcome measures (self-reported moderate-vigorous PA, self-reported walking, accelerometer steps, and aerobic fitness) using multilevel mixed-effects analyses. Significant condition by barrier interaction effects for the accelerometer steps outcome were found for material hardships, general health, depressive symptoms, neighborhood crime rate, and perceived barriers to PA. For aerobic fitness, intervention effects were moderated by material hardships and perceived pain. Increases in the outcome variables were greater for the conditions in which group sessions were supplemented with personal and/or automated calls. Among participants with greater barriers to PA, supplementing the intervention group meetings with between-session personal and/or automated phone calls may be an effective way to strengthen intervention effects. These results may inform the use of treatment supplements in the context of adaptive interventions.

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1. Introduction

African American women have a higher prevalence of hypertension, cardiovascular disease, diabetes and obesity compared to non-Hispanic White women (Mozaffarian et al., 2015). Physical activity (PA) is a well-established method of reducing disease risks associated with inactivity and obesity (Mozaffarian et al., 2015). Current guidelines recommend participating in moderate PA (brisk walking) for 150 min/week in episodes of at least 10 min (US Department of Health and Human Services, 2008). However, only 35% of Chicago-area African American women meet these recommendations compared to 47% of women countywide (Liao et al., 2011).

Many African American women have substantial barriers to PA. Frequently reported barriers to leisure-time PA include demands of work, school, home, children, partners, and social obligations (Pekmezi et al., 2013; Siddiqi et al., 2011); mental fatigue from physically demanding jobs (Forthofer et al., 2016); perceptions that "leisure time" does not exist for them (Airhihenbuwa et al., 1995; Yeager et al., 1993); or is an unaffordable indulgence (Kriska and Rexroad, 1998; Wilbur et al., 2002); and that adequate PA is obtained by living a "busy life" (Wilbur et al., 2002). Additional barriers include health problems (Bopp et al., 2006) that may develop or worsen when obese, sedentary individuals increase their PA. Neighborhood environmental characteristics also present barriers to PA, including concerns about harassment, feeling unsafe at local parks, and gang activity (Baruth et al., 2014). Neighborhood socioeconomic factors have been linked to health behaviors such as PA (Diez Roux, 2016). Inequitable distribution of resources such as exercise facilities, walkable sidewalks, and street lights may present additional barriers to increasing PA among lower income African American women (Mama et al., 2015).

In addition to limiting levels of PA, barriers to PA may also moderate the impact of interventions to increase PA. To date, few studies examine moderators of intervention effects on PA among adults (Luten et al., 2016). The existing studies of moderation in PA interventions often focus on demographic factors such as gender (Luten et al., 2016; Wilcox et al., 2009), age (van Stralen et al., 2010; Wilcox et al., 2009), and education (Luten et al., 2016). These studies also have identified psychosocial moderators, including self-efficacy (Luten et al., 2016), motivation (van Stralen et al., 2010), and social support (Wilcox et al., 2009).

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A review of 29 PA interventions with African American women finds that, although many interventions used some type of cultural adaptation, participants generally received the same intervention regardless of their individual barriers to PA (Whitt-Glover and Kumanyika, 2009). Evidence from moderation analyses, coupled with recent developments in adaptive interventions, suggest that participants may benefit from customizing interventions based on characteristics of the individual (Wilbur et al., 2016).

Among the recommendations provided by the 2010 Scientific Statement from the American Heart Association for interventions to promote PA changes are (a) use of group sessions with cognitive-behavioral strategies; (b) use of motivational interviewing (MI) for individuals resistant to behavioral change; and (c) use of electronic-based programs (Artinian et al., 2010). A review of PA interventions confirmed that theory-driven group interventions combining guidance, self-management and on-going support were effective in increasing PA among disadvantaged African American women (Cleland et al., 2012). MI is a client-centered counseling approach designed to explore and resolve ambivalence about changing behavior (Miller and Rollnick, 2002). A study of the use of MI telephone in healthy African Americans found an increase in PA, but the effect was not greater than culturally targeted materials alone (Resnicow et al., 2005). Group support supplemented by MI either by phone or in person may be successful in helping women overcome barriers to becoming more physically active. For women who report being self-conscious and/or feeling guilty when they do not become more physically active, automated telephone systems offer anonymity liked by participants (Ingram et al., 2011; Kaplan et al., 2003) and have the advantage of reducing reliance on reading skills needed for mailed materials.

Building upon focus groups with African American women (Wilbur et al., 2002), we developed a culturally relevant PA intervention, the Women's Lifestyle PA Program (Ingram et al., 2011). Using a randomized clinical trial (RCT), we tested three study conditions designed to increase adherence to lifestyle PA in midlife (ages 40–65) African American women. Women in all three conditions attended six group meetings. In addition to group meetings, one condition received 11 MI telephone calls, one condition received 11 automated telephone calls with motivational problem-solving tips, and one condition received no additional support. All three conditions had significant improvements in PA, but there were no significant differences between conditions (Wilbur et al., 2015). By testing moderators of the three intervention conditions within this RCT, we expect to identify specific factors that may explain variation in treatment effects and inform development of future customization in the context of adaptive interventions.

The aim of this paper is to determine whether individual barriers (demographic, physical health, psychological health, neighborhood factors, perceived barriers to PA, social support for PA) moderate treatment effects on increases in PA. The specific research question is: What are the modifiers of treatment impact on change in adherence to PA?

2. Methods

2.1. Design

Three treatment conditions were compared using a cluster-randomized, Latin-square design in which the order of intervention delivery was counterbalanced across six sites (Winer, 1971). Full details of the design are available elsewhere (Wilbur et al., 2015). Institutional Review Boards from two universities approved the study (registered clinical trial NCT01700894).

2.2. Sample

The sample consisted of 288 African American women between the ages of 40 and 65, who were sedentary (participated in moderate-vigorous PA <3 times per week), had access to a telephone, and could attend group meetings (Wilbur et al., 2015, 2013). Those with health issues that interfered with PA were excluded. Six sites were in areas that were either predominantly African American (>90%) or near low-income census tracts (U. S. Census Bureau, 2014).

To maximize study retention, women provided multiple means of contacting them and were compensated $40 for completing each study assessment (baseline, 24, and 48 weeks). At study completion, participants were given a pedometer.

2.3. Intervention

2.3.1. Group meetings

The group meeting component of the intervention was identical across all study conditions and consisted of five, two-hour group meetings over a 24-week adoption phase followed by a sixth "booster" meeting midway through the 24-week maintenance phase (Fig. 1). The intervention was manualized and six group facilitators were predominately female African American registered nurses.

2.3.2. Individual goal-setting and feedback

The goal was to increase each woman's PA above baseline by at least 3000 steps per day (Wilde et al., 2001), at a moderate walking pace to reduce joint load in individuals who may be overweight or obese (Browning and Kram, 2007). Baseline steps were obtained from blocked (no data displayed) accelerometers worn the week before the first group meeting. Weight loss was not mentioned with participants; rather, the primary goal was maintaining one's weight.

2.3.3. Group discussion

Consistent with the social cognitive theory (Bandura, 1997), group discussions began with a short DVD featuring African American women demonstrating skills, sharing experiences, and talking about challenges. The facilitator then led a 40-minute discussion, providing role-modeling and encouraging problem solving. All discussions addressed barriers and misinformation identified in earlier focus groups (Ingram et al., 2011; Wilbur et al., 2002). The last group discussion focused on anticipating such disincentives and handling relapses.

2.3.4. Personal motivational telephone calls

Six groups (96 participants) received the personal call condition (Group + PC). Between group meetings, these women received calls from their nurse facilitator, who used motivational interviewing techniques to help participants explore and resolve ambivalence about increasing their PA (Emmons and Rollnick, 2001) and tailored the discussion to match each woman's needs, experiences, barriers, motivation, and confidence (Resnicow et al., 1999). During maintenance, one

Condition	Adoption Phase (weeks 1-24)											Maintenance Phase (weeks 24-48)		
Group+AC	👥	☎	☎ 👥	☎	☎ 👥	☎	☎ 👥	☎ 👥		☎		☎	👥	☎
Group+PC	👥	☎	☎ 👥	☎	☎ 👥	☎	☎ 👥	☎ 👥		☎		☎	👥	☎
Group Only	👥		👥		👥		👥	👥					👥	

👥 Group Meeting ☎ Telephone Call (AC = Automated, PC = Personal)

Fig. 1. Phases of the intervention by treatment condition.

Table 1
Participant characteristics at baseline by study condition; Chicago, Illinois.

	Intervention condition								
	Total ($n = 260$)		Group only ($n = 88$)		Group + AC ($n = 86$)		Group + PC ($n = 86$)		p
Age, M (SD)	53.5 (6.5)		53.6 (6.4)		53.3 (6.9)		53.5 (6.3)		0.945
MVPA (min/week), M (SD)	151.1 (217.4)		150.0 (225.6)		181.4 (198.4)		121.9 (225.3)		0.200
Leisure time MVPA (min/week), M (SD)	109.8 (174.3)		113.5 (189.3)		126.3 (150.4)		89.5 (180.4)		0.373
Walking (min/week), M (SD)	165.8 (204.5)		145.7 (183.4)		179.0 (190.4)		173.2 (237.0)		0.520
Accelerometer steps (steps/day), M (SD)	5643.9 (2219.8)		5345.8 (1957.7)		5710.7 (2392.0)		5866.6 (2275.0)		0.335
Aerobic fitness (steps/2 min), M (SD)	82.8 (15.9)		83.3 (15.6)		84.9 (16.6)		80.1 (15.4)		0.126
	n	%	*n*	%	*n*	%	*n*	%	
Married or living with partner	101	38.8	39	44.3	27	31.4	35	40.7	0.198
One or more children under age 18	95	36.5	29	33.0	32	37.2	34	39.5	0.658
Education college or higher	128	49.2	49	55.7	43	50.0	36	41.9	0.187
Employed (full-time or part-time)	193	74.2	62	70.5	59	68.6	72	83.7	0.047
Family income									0.759
<$20,000	30	12.1	11	13.1	11	13.6	8	9.6	
$20,000–$39,999	66	26.6	19	22.6	26	32.1	21	25.3	
$40,000–$59,999	55	22.2	20	23.8	17	21.0	18	21.7	
≥$60,000	97	39.1	34	40.5	27	33.3	36	43.4	
Economic hardship									0.166
No hardship	142	55.7	44	51.8	43	50.6	55	64.7	
One hardship	57	22.4	24	28.2	18	21.2	15	17.6	
More than one hardship	56	22.0	17	20.0	24	28.2	15	17.6	

Note: numbers may not total the full sample size due to missing data.

motivational call was made before and one after the booster group meeting (total 2). If barriers were present, women were prompted to solve their own barriers. Only then did the facilitator ask permission to provide information or advice that had worked for other people.

2.3.5. Automated motivational telephone calls

Six groups (97 participants) received the automated call condition (Group + AC) between group visits. The content and scheduled delivery was structured to match the person-delivered calls and was recorded by an African American singer/actress. Each call offered menu selections for information. The 15 topics (23 items) included ways to incorporate PA into daily life and the benefits of becoming more active, with the tips and information changing to reflect seasons of the year (Appendix). To conclude the call, participants were asked to enter their next step goal and their confidence (0 − 10) in meeting the goal. Women with confidence below 8 were encouraged to adjust goals to increase confidence. Each call ended with advice matched to program content (Appendix).

2.3.6. No telephone calls

Six groups (95 women) had no contact (group only) except reminder calls for upcoming meetings and automated reminder calls to report steps in the automated telephone computer-linked system.

2.4. Measures

Baseline measures of demographic characteristics, health status, neighborhood characteristics, perceived barriers to PA, and social support for PA were used to model barriers to increases in PA. Each barrier was dichotomized to ease interpretation and utilization of the results.

2.4.1. Demographic characteristics

Demographics included presence of children and baseline employment. *Material hardship* was measured using questions from the U.S. Census Bureau's Survey of Income and Program Participation (Bauman, 1998) about food adequacy and ability to meet housing, utility, telephone, and medical expenses.

2.4.2. Health status

Health status measures included general health, global pain, body mass index, and depressive symptoms. *General health* was measured with an item from the Behavioral Risk Factor Surveillance System asking participants to their overall health status from excellent to poor (Behavioral Risk Factor Surveillance System, 2010).

Table 2
Cutpoints for barriers to increasing physical activity; Chicago, Illinois.

Variable	M (SD)	Range	Cutpoint[a]	Cases above/below cutpoint n (%)
Demographic				
Children in household	–	Y/N	Y	94 (36.5)
Employed	–	Y/N	Y	193 (74.2)
Number of hardships	0.66 (0.82)	0–2	≥2	56 (22.0)
Physical health				
General health	3.25 (0.80)	1–5	<3	34 (13.2)
Pain	9.26 (5.62)	4–34	≥11	82 (32.4)
BMI (kg/m^2)	35.30 (7.51)	21–61	≥40	59 (22.7)
Psychological health				
Depression	8.78 (7.12)	0–38	≥16	40 (15.4)
Neighborhood characteristics				
Perceived walkability	3.08 (0.42)	1.6–3.9	≤2.8	64 (24.8)
Assault/battery rate	649.30 (519.03)	0–2564	≥1000	69 (26.8)
Perceived barriers to PA				
Perceived barriers for PA	22.62 (9.74)	0–55	≥29	68 (26.4)
Social support				
Support from family	2.10 (1.08)	1–5	≤1.5	95 (37.1)
Support from friends	2.16 (1.06)	1–5	≤1.5	85 (34.0)

[a] Variables were dichotomized as indicated such that a value of one represented a barrier to adherence in increasing physical activity (i.e., a lower likelihood of increasing PA).

Table 3
Change in adherence to physical activity by condition for participants with barriers to increasing physical activity; Chicago, Illinois.

Barrier	3-way interaction[a]		Slope estimates[b]						Slope contrasts[c]					
			AC		PC		G		AC-G		PC-G		AC-PC	
	F	*p*	*Est*	*SE*	*Est*	*SE*	*Est*	*SE*	*d*	*p*	*d*	*p*	*d*	*p*
MVPA (min/week)														
Demographic														
Children in household	1.48	0.229	81.09	32.37	96.40	31.41	183.36	34.01	−0.47	0.030	−0.40	0.061	−0.07	0.735
Employed	0.94	0.394	97.63	24.01	82.60	21.73	109.84	23.42	−0.06	0.716	−0.13	0.395	0.07	0.643
Number of hardships	0.47	0.628	74.37	37.48	54.50	47.41	144.71	44.53	−0.32	0.228	−0.42	0.167	0.09	0.743
Physical health														
General health	0.58	0.561	112.50	55.87	76.61	49.52	65.83	61.76	0.22	0.576	0.05	0.892	0.17	0.631
Pain	0.41	0.665	85.50	37.16	48.87	33.37	91.44	36.44	−0.03	0.909	−0.20	0.390	0.17	0.464
BMI	0.34	0.712	48.16	42.37	58.82	42.37	126.43	40.30	−0.36	0.182	−0.31	0.249	−0.05	0.859
Psychological health														
Depression	0.14	0.868	96.14	55.77	76.41	46.25	154.04	51.30	−0.27	0.446	−0.36	0.262	0.09	0.786
Neighborhood characteristics														
Perceived walkability	0.04	0.960	81.18	44.82	56.88	37.72	101.09	38.54	−0.09	0.737	−0.20	0.413	0.11	0.679
Assault/battery rate	0.07	0.933	75.28	35.58	75.63	37.94	130.15	45.08	−0.25	0.340	−0.25	0.356	0.00	0.995
Perceived barriers to PA														
Perceived barriers for PA	2.34	0.099	138.95	35.96	63.75	42.61	94.06	36.91	0.21	0.385	−0.14	0.591	0.35	0.179
Social support														
Support from family	1.07	0.345	42.14	35.55	97.02	32.74	130.74	29.97	−0.41	0.058	−0.16	0.448	−0.25	0.257
Support from friends	0.27	0.765	83.78	35.68	67.25	32.75	92.07	33.31	−0.04	0.865	−0.11	0.596	0.08	0.733
Leisure time MVPA (min/week)														
Demographic														
Children in household	1.25	0.289	86.95	27.83	83.60	27.00	152.84	29.23	−0.38	0.104	−0.40	0.083	0.02	0.931
Employed	1.24	0.290	92.29	20.59	80.00	18.64	89.03	20.09	0.02	0.910	−0.05	0.742	0.07	0.659
Number of hardships	0.45	0.639	81.88	32.49	34.00	41.10	105.00	38.61	−0.13	0.647	−0.41	0.209	0.27	0.362
Physical health														
General health	0.16	0.855	92.73	48.08	71.25	42.62	72.50	53.15	0.12	0.778	−0.01	0.985	0.12	0.738
Pain	0.17	0.840	76.50	31.97	49.84	28.71	94.90	31.35	−0.11	0.681	−0.26	0.290	0.15	0.535
BMI	0.17	0.844	67.11	36.44	54.47	36.44	104.64	34.66	−0.22	0.456	−0.29	0.319	0.07	0.807
Psychological health														
Depression	1.17	0.312	69.55	47.66	66.56	39.52	165.58	43.84	−0.55	0.139	−0.57	0.095	0.02	0.962
Neighborhood characteristics														
Perceived walkability	0.05	0.953	56.91	38.54	56.56	32.44	83.48	33.13	−0.15	0.602	−0.15	0.562	0.00	0.994
Assault/battery rate	0.03	0.966	67.61	30.51	65.94	32.53	84.71	38.65	−0.10	0.729	−0.11	0.711	0.01	0.970
Perceived barriers to PA														
Perceived barriers for PA	1.49	0.228	110.95	30.80	63.33	36.50	69.38	31.61	0.24	0.347	−0.03	0.901	0.27	0.320
Social support														
Support from family	0.81	0.448	46.80	30.39	80.81	27.98	102.77	25.61	−0.32	0.160	−0.13	0.563	−0.20	0.411
Support from friends	0.05	0.952	68.58	30.40	49.25	27.90	78.88	28.38	−0.06	0.805	−0.17	0.457	0.11	0.640
Walking (min/week)														
Demographic														
Children in household	0.52	0.593	100.55	30.94	133.46	30.01	126.98	32.50	−0.13	0.556	0.03	0.884	−0.16	0.446
Employed	1.41	0.246	102.08	22.76	119.79	20.60	102.22	22.20	0.00	0.996	0.09	0.562	−0.09	0.564
Number of hardships	0.72	0.486	92.19	35.53	109.00	44.95	45.44	42.22	0.23	0.398	0.31	0.304	−0.08	0.769
Physical health														
General health	1.35	0.261	154.77	52.66	203.04	46.68	97.50	58.22	0.28	0.466	0.52	0.158	−0.24	0.493
Pain	1.56	0.212	120.90	35.19	128.95	31.6	66.35	34.51	0.27	0.269	0.31	0.182	−0.04	0.865
BMI	0.48	0.618	110.53	40.06	158.68	40.06	140.00	38.11	−0.14	0.594	0.09	0.736	−0.24	0.396
Psychological health														
Depression	1.55	0.215	41.59	52.67	129.84	43.67	154.62	48.45	−0.55	0.115	−0.12	0.704	−0.43	0.198
Neighborhood characteristics														
Perceived walkability	0.35	0.702	54.71	42.42	87.5	35.70	55.11	36.47	0.00	0.994	0.16	0.526	−0.16	0.555
Assault/battery rate	0.03	0.970	88.61	33.58	100.00	35.80	96.62	42.54	−0.04	0.883	0.02	0.952	−0.06	0.817
Perceived barriers to PA														
Perceived barriers for PA	0.33	0.719	119.37	34.58	157.08	40.98	124.69	35.49	−0.03	0.915	0.16	0.551	−0.18	0.483
Social support														
Support from family	0.30	0.744	93.30	34.14	109.11	31.43	124.46	28.77	−0.15	0.486	−0.07	0.719	−0.08	0.733
Support from friends	0.34	0.714	117.48	34.66	99.25	31.81	84.57	32.35	0.16	0.488	0.07	0.747	0.09	0.699
Accelerometer steps (steps/day)														
Demographic														
Children in household	1.05	0.354	159.3	272.3	790.1	243.6	−54.7	305.6	0.09	0.602	0.37	0.032	−0.28	0.086
Employed	0.84	0.432	339.8	185.7	545.2	165.7	38.6	184.5	0.13	0.251	0.22	0.043	−0.09	0.410
Number of hardships	3.37	0.037	−199.9	286.5	1149.2	357.6	105.1	348.0	−0.13	0.500	0.46	0.038	−0.59	0.004
Physical health														
General health	2.42	0.092	−822.1	433.8	683.0	357.8	−153.3	521.5	−0.29	0.326	0.37	0.188	−0.66	0.008
Pain	0.08	0.924	115.4	269.4	567.6	273.4	113.2	292.6	0.00	0.996	0.20	0.258	−0.20	0.240
BMI	0.21	0.807	81.4	302.5	239.7	351.3	109.0	339.6	−0.01	0.952	0.06	0.789	−0.07	0.733
Psychological health														
Depression	4.96	0.008	1083.5	383.1	760.6	360.4	−573.3	375.8	0.73	0.002	0.59	0.011	0.14	0.540
Neighborhood characteristics														
Perceived walkability	0.26	0.773	−155.8	329.4	391.5	309.1	14.2	297.7	−0.07	0.702	0.17	0.381	−0.24	0.227

Table 3 (*continued*)

Barrier	3-way interaction[a]		Slope estimates[b]						Slope contrasts[c]					
			AC		PC		G		AC-G		PC-G		AC-PC	
	F	*p*	*Est*	*SE*	*Est*	*SE*	*Est*	*SE*	*d*	*p*	*d*	*p*	*d*	*p*
Assault/battery rate	2.46	0.088	828.2	271.7	755.8	279.0	−88.7	340.6	0.40	0.037	0.37	0.057	0.03	0.853
Perceived barriers to PA														
Perceived barriers for PA	2.65	0.073	−24.9	274.6	1153.7	332.8	7.0	290.8	−0.01	0.937	0.51	0.010	−0.52	0.007
Social support														
Support from family	0.37	0.690	386.4	261.6	499.0	243.4	212.6	237.3	0.08	0.623	0.13	0.401	−0.05	0.753
Support from friends	0.51	0.603	405.8	277.8	636.3	249.0	54.4	283.7	0.15	0.377	0.26	0.125	−0.10	0.538
Aerobic fitness (steps/2 min)														
Demographic														
Children in household	0.24	0.783	2.97	1.70	5.21	1.66	3.06	1.78	−0.01	0.970	0.13	0.378	−0.14	0.346
Employed	0.36	0.698	2.96	1.23	3.90	1.15	3.19	1.19	−0.01	0.893	0.04	0.666	−0.06	0.575
Number of hardships	4.00	0.020	1.56	1.94	8.75	2.50	−0.97	2.38	0.16	0.411	0.61	0.005	−0.45	0.024
Physical Health														
General health	1.93	0.147	5.40	2.90	8.54	2.64	0.21	3.23	0.32	0.233	0.52	0.047	−0.20	0.425
Pain	3.50	0.032	6.66	1.95	3.29	1.75	1.11	1.87	0.35	0.041	0.14	0.394	0.21	0.201
BMI	2.62	0.075	7.49	2.21	2.94	2.32	2.92	2.06	0.29	0.132	0.00	0.993	0.28	0.158
Psychological health														
Depression	0.02	0.976	4.05	3.04	4.74	2.46	3.77	2.60	0.02	0.944	0.06	0.786	−0.04	0.860
Neighborhood characteristics														
Perceived walkability	0.06	0.942	3.49	2.33	5.11	2.05	4.85	2.02	−0.09	0.659	0.02	0.929	−0.10	0.603
Assault/battery rate	0.87	0.420	3.05	1.85	7.38	1.96	3.86	2.36	−0.05	0.787	0.22	0.253	−0.27	0.109
Perceived barriers to PA														
Perceived barriers for PA	0.46	0.634	2.64	1.86	4.49	2.40	1.50	1.99	0.07	0.676	0.19	0.338	−0.12	0.541
Social support														
Support from family	1.62	0.199	0.41	1.84	5.50	1.73	3.88	1.57	−0.22	0.154	0.10	0.488	−0.32	0.045
Support from friends	1.22	0.298	3.52	1.86	7.26	1.77	3.60	1.82	0.00	0.976	0.23	0.151	−0.23	0.147

Notes:

[a] The overall test of the three-way interaction of barrier × condition × time. Slope contrasts were not interpreted unless the three-way interaction was significant at $p < 0.10$.

[b] The slopes estimates represent the coefficient for linear change over time (per assessment) among participants who were coded positive for each obstacle to adherence to physical activity.

[c] The contrasts are presented in units of standardized mean differences in rates of change (effect size *d*). Effect sizes were estimated using pooled standard deviations of the baseline outcome measures.

Global pain was measured using as the sum of four items assessing pain (average, worst, least, and interference with PA) on a 10-point rating scale. In the current sample, this measure demonstrated good internal consistency ($\alpha = 0.86$).

2.4.2.1. Body mass index. Height was measured to the nearest 1/16 in. using the Seca Portable Stadiometer Model 213. Weight was measured to the nearest 1/4 lb using a balance beam digital scale (Seca Brand SE 803 scale), with participants standing in light clothing and without shoes. Body mass index (BMI) was calculated by dividing weight (kilograms) by height (meters) squared (wt/ht^2); (American College of Sports Medicine, 2010).

The 20-item *Center for Epidemiological Studies-Depression* (CES-D) scale was used to measure current depressive symptoms (Radloff, 1977). Items were rated on a 4-point scale and summed for a total score. A score of 16 or above represents the criteria for elevated depression (Boyd et al., 1982). This scale demonstrated good internal consistency in the current sample ($\alpha = 0.81$).

2.4.3. Neighborhood characteristics

Neighborhood characteristics were assessed with a subjective measure of neighborhood walkability as well as violent crime rate. Neighborhood walkability was measured with a 28-item version of the *Neighborhood Environment Walkability Scale* (NEWS; (Cerin et al., 2006). The NEWS measures respondents' perceptions of characteristics in their neighborhoods that are conducive to walking. The scale demonstrated good internal consistency ($\alpha = 0.88$) in the current sample.

Rates (incidence per 100,000 residents) of *aggravated assaults/batteries* for the 2009 calendar year were obtained from the Chicago Police Department and Illinois State Police (United States Department of Justice, 2013). Rates within Chicago were calculated for each census tract, while suburban rates were calculated for the entire community.

2.4.4. Perceived barriers to physical activity

Perceived barriers to PA were measured with 15 items from the Twin City Walking Survey (Forsyth et al., 2009) supplemented with two items from the St. Louis Environment and Physical Activity Instrument (lack of child-care assistance and lack of a safe place to be physically active); (Brownson et al., 2004) and one item created by the authors based on focus groups used to develop the intervention (fear that hairstyle would be ruined); (Ingram et al., 2011; Wilbur et al., 2002). The scale demonstrated good internal consistency ($\alpha = 0.82$) in the current sample.

2.4.5. Social support

Social support was measured using Sallis' *Social Support and Exercise Survey* (Sallis et al., 1987) with modifications to assess support for PA. The measure consists of 13 activities rated on a 5-point scale separately from support for family and from friends. Both scales demonstrated excellent internal consistency ($\alpha = 0.92$ for each) in the current sample.

2.4.6. Adherence to physical activity

Adherence to PA at baseline, 24, and 48 weeks was assessed directly by self-reported PA questionnaires and by accelerometry. Adherence was also measured indirectly by an aerobic fitness field test.

2.4.6.1. Self-reported PA. Minutes per week of moderate to vigorous lifestyle PA were measured with the 30-item, *Community Healthy Activity Model Program for Seniors (CHAMPS)* PA questionnaire (Stewart et al., 2001). Developed for middle-aged and older adults and adapted for use with African Americans (Resnicow et al., 2003), the CHAMPS covers a variety of daily activities by asking participants to estimate the frequency and average total amount of time spent weekly doing each

activity over the past two weeks. Each item has an assigned metabolic equivalent (MET) value based on the 2000 Compendium of Physical Activities (Ainsworth et al., 2000), with moderate physical activities defined by MET values ≥3.0 to <6.0 and vigorous by MET values ≥6.0. We calculated the average minutes per week for overall moderate to vigorous physical activities. Six-month reliability for moderate-vigorous intensity PA was ICC = 0.66 (Stewart et al., 2001).

2.4.6.2. Accelerometer. Women were given a Lifecorder EX (NL2200) accelerometer and instructed to wear it daily during waking hours throughout the study. The accelerometer stores 200 days of steps and records time, date, total steps, and bout steps for each hour of the day using a piezo-electric strain gauge (Crouter et al., 2005). Lifecorder steps compared to observed steps were accurate to ±1–3% (Crouter et al., 2003). The Lifecorder EX does not record non-walking activity such as swimming or biking.

Step counts were selected as the accelerometry measure to match the study focus on increasing walking. The present study used adaptations of criteria (4+ more days with 10+ hours of wear time) used by Troiano and colleagues (Troiano et al., 2008). Data were screened to exclude days with <1200 steps, the minimum number of steps taken by participants on over 98% of days during blinded baseline measurement. Fewer than 1200 steps likely represented either a device malfunction or failure to wear the accelerometer for an adequate amount of time. Weeks with fewer than three days of valid data were excluded from analyses. Days with valid step data in the week prior to the first group meeting were summed and divided by the total number of days with valid data to obtain mean baseline steps per day. The steps accumulated during weeks with valid data in the month before and after the 24- and 48-week assessments were summed and divided by the total number of weeks with valid data to obtain mean steps per day at 24 and 48 weeks.

2.4.6.3. Aerobic fitness. An estimate of aerobic fitness was determined with the 2-minute step test, a part of the Senior Fitness Test recommended for use in low fit older adults (Rikli and Jones, 1999). In this field test participants step in place, lifting their knees to designated point over a two-minute period. Intraclass reliability was 0.89. Criterion validity was established with treadmill time to 85% predicted maximum heart rate (Rikli and Jones, 1999).

2.5. Analysis

2.5.1. Coding of barriers to physical activity change

All measures of barriers were dichotomized such that a value of one was in the direction hypothesized to represent the presence of a barrier to increasing PA. For BMI and depression, cutoffs were based on established thresholds: 40 (morbidly obese) for BMI and 16 (sub-clinical depressive symptoms) for depression. The remaining continuous measures were dichotomized at natural breaks in the distributions or at approximately the top quartile of participants.

2.5.2. Data analytic strategy

Differential intervention effects on changes in adherence to PA by presence of baseline barriers were examined using a series of multilevel mixed-effects analyses. These analyses included condition and barriers as between-person factors (level 2) and time as a within-person factor (level 1). The effect of primary interest was the three-way interaction of barriers x condition x time. Planned contrasts were used to evaluate differential change over time (from baseline through 48 weeks) for the Group + AC and Group + PC conditions relative to the Group-only condition. Planned contrasts were examined and interpreted only for overall three-way interaction effects significant at the $p < 0.10$ level. Significance levels of $p < 0.05$ were used for all other statistical tests. Effect sizes were estimated using baseline standard deviations as the denominator.

3. Results

3.1. Sample description

Of the 288 women who completed baseline assessments and were randomized, 260 (90.3%) completed the study (i.e., 24- and 48-week assessments) and were included in these analyses. Age was the only demographic difference (Table 1) between completers ($M = 53.5$, $SD = 6.5$) and non-completers ($M = 49.3$, $SD = 5.8$).

At baseline, there were no differences by condition for any of the five measures of adherence to PA (Table 1). Slightly more than one-third of participants had one or more children under the age of 18 and nearly half reported having a college degree or higher. Nearly 60% reported a family income under $60,000 and 44% reported one or more material hardships in the past year. The only significant demographic difference by study condition was for employment. The women in the Group + PC condition were more likely to be employed than the other two conditions. For most barriers (Table 2), one-fourth to one-third of participants were coded positive.

3.2. Interaction between condition and barriers on change in adherence

For self-reported minutes of MVPA per week, there was a significant ($p < 0.10$) interaction between condition and perceived barriers to PA (Table 3). Among those with high perceived barriers, participants in the Group + AC condition increased their MVPA by 45 min per week more than those in the Group-Only condition and by 75 min more than those in the Group + PC condition; however, both differences were non-significant. There were no significant interaction effects for self-reported measures of leisure time MVPA or walking.

For accelerometer steps per day, there were significant interactions between study condition and five barriers: (a) material hardships, (b) general health, (c) depression, (d) neighborhood assault rate, and (e) perceived barriers to PA. Among those with material hardships, participants in the Group + PC condition showed increases in accelerometer steps per day relative to participants in the both the Group-Only and Group + AC conditions such that participants in the Group + PC condition increased by 1044 steps per day more than those in the Group-Only condition (1149.2 vs. 105.1) and by 1349 steps per day more than those in the Group + AC condition. These differences translated into estimated effects sizes of $d = 0.46$ and $d = 0.59$, respectively. Among those with poor general health, participants in the Group + PC condition showed increases of 1505 steps per day more than those in the Group + AC condition ($d = 0.66$). Among those with elevated depressive symptoms, participants in the Group + AC condition as well as the Group + PC condition showed increases of 1657 steps per day more than those in the Group-Only condition ($d = 0.73$). In addition, those in the Group + PC condition increased by 1376 steps per day more than those in the Group-Only condition $d = 0.59$). Among those living in neighborhoods with high assault rates, participants in the Group + AC condition showed increases of 917 steps per day more than those in the Group-Only condition ($d = 0.40$). Finally among those with high perceived barriers, participants in the Group + PC condition showed increases of 1146 steps per day more than those in the Group-Only condition ($d = 0.51$).

For aerobic fitness, there were significant interactions between study condition and two barriers: (a) number of hardships and (b) perceived pain. Among those with two or more hardships, participants in the Group + PC condition increased the number of steps taken during the fitness test by 9.7 more than those in the Group-Only condition ($d = 0.61$). For those with higher pain scores, participants in the Group + AC condition increased the number of steps taken during the fitness test by 5.6 more than those in the Group-Only condition ($d = 0.35$).

4. Discussion

By examining barriers to PA as moderators of treatment effects, we were able to identify specific barriers associated with differential impact of supplemental calls between group sessions. The most notable of these effects were found for participants with elevated depressive symptoms. For these participants, both call conditions improved their number of steps significantly more than the Group-Only condition. These findings are important in the context of research linking depressive symptoms to lower levels of PA (Patten et al., 2009; van Gool et al., 2003) and showing that PA interventions led to reductions in depressive symptoms (Conn, 2010). The MI and problem-solving focus of the telephone calls may have improved self-efficacy for PA, which may be particularly important for participants with depressive symptoms (Kangas et al., 2015). In addition, the MI and problem solving were likely for overcoming specific barriers to PA such as material hardships, neighborhood crime, and perceived barriers to PA. Additional research is needed to understand the mechanism of these moderation effects.

These results build upon prior analyses of moderation of PA interventions in important ways. First, all potential moderators were selected based on an a priori rationale that they served to interfere with increasing PA. Prior studies have often included demographic variables without specific hypotheses about the direction of moderation (Luten et al., 2016; van Stralen et al., 2010; Wilcox et al., 2009). Second, the design of the present study allowed tests of moderation of intervention supplements rather than testing moderation of treatment versus control groups. Testing moderation of supplemental phone calls is more directly informative for future research building adaptive interventions. The problem-solving focus of the telephone calls may explain their benefit for women facing barriers to PA. Finally, this study focused on a sample of African American women, a population at particular risk for negative health outcomes associated with inactivity. These results contribute to a small but growing literature regarding moderators of PA interventions.

This study has a few limitations. Because these are secondary analyses, the original study was neither designed nor powered to test the moderated effects presented in this paper. For ease of analysis and interpretation, barriers were dichotomized; however, most measures did not have clinical guidelines to inform cutoff scores. As such, the cutoffs that were selected may not represent optimal scores for dichotomization. Further, generalizability is likely limited by the focus on urban African American midlife women who self-selected for study participation.

Despite the noted limitations, the present study provides evidence that intervention supplements (between-group telephone calls) may provide significant benefits for participants facing more and greater barriers to increasing adherence to PA, especially depression. Although not designed to test the impact of adaptive interventions, these results are consistent with the concept that treatment augmentation may be necessary for some participants based on pre-existing characteristics or treatment non-response (Almirall et al., 2014). Future studies should employ research designs to specifically test adaptive interventions to increase adherence to PA.

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