ORIGINAL RESEARCH

Changes in CVD risk factors in the activity counseling trial

Meghan Baruth[1]
Sara Wilcox[1]
James F Sallis[3]
Abby C King[4,5]
Bess H Marcus[6]
Steven N Blair[1,2]

[1]Department of Exercise Science, [2]Department of Epidemiology and Biostatistics, Arnold School of Public Health, University of South Carolina, Public Health Research Center, Columbia, SC, USA; [3]Department of Psychology, San Diego State University, San Diego, CA, USA; [4]Department of Health Research and Policy, [5]Stanford Prevention Research Center, Department of Medicine, Stanford University School of Medicine, Stanford, CA, USA; [6]Behavioral and Social Sciences Section, Brown University Program in Public Health, Providence, RI, USA

Correspondence: M Baruth
Department of Exercise Science,
Arnold School of Public Health, University of South Carolina, Public Health Research Center, 921 Assembly Street, Columbia, SC 29208, USA
Tel +1 803 777 2354
Fax +1 803 777 0558
Email stritesk@mailbox.sc.edu

Abstract: Primary care facilities may be a natural setting for delivering interventions that focus on behaviors that improve cardiovascular disease (CVD) risk factors. The purpose of this study was to examine the 24-month effects of the Activity Counseling Trial (ACT) on CVD risk factors, to examine whether changes in CVD risk factors differed according to baseline risk factor status, and to examine whether changes in fitness were associated with changes in CVD risk factors. ACT was a 24-month multicenter randomized controlled trial to increase physical activity. Participants were 874 inactive men and women aged 35–74 years. Participants were randomly assigned to one of three arms that varied by level of counseling, intensity, and resource requirements. Because there were no significant differences in change over time between arms on any of the CVD risk factors examined, all arms were combined, and the effects of time, independent of arm, were examined separately for men and women. Time × Baseline risk factor status interactions examined whether changes in CVD risk factors differed according to baseline risk factor status. Significant improvements in total cholesterol, high-density lipoprotein cholesterol (HDL-C) and low-density lipoprotein cholesterol, the ratio of total cholesterol to HDL-C, and triglycerides were seen in both men and women who had high (or low for HDL-C) baseline levels of risk factors, whereas significant improvements in diastolic blood pressure were seen only in those men with high baseline levels. There were no improvements in any risk factors among participants with normal baseline levels. Changes in fitness were associated with changes in a number of CVD risk factors. However, most relationships disappeared after controlling for changes in body weight. Improvements in lipids from the ACT interventions could reduce the risk of coronary heart disease in people with already high levels of lipids by 16%–26% in men and 11%–16% in women. Interventions that can be implemented in health care settings nationwide and result in meaningful population-wide changes in CVD risk factors are needed. The ACT physical activity interventions produced substantial improvements among men and women with elevated CVD risk factors.

Keywords: primary care counseling, cardiovascular disease risk factors, physical activity, fitness, behavioral intervention

Introduction

Cardiovascular disease (CVD) accounts for 25% of all deaths in the US.[1] Hypertension[2] and hyperlipidemia[3] are two established risk factors for CVD. Results from the National Health and Nutrition Examination Survey (NHANES) indicate that among adults aged 20 years and older, 21% have elevated low-density lipoprotein cholesterol (LDL-C)[4] and 29% have hypertension ($\geq$140/90 mm Hg).[5] Physical activity (PA), a major modifiable risk factor for CVD, is associated with a decreased risk for both hypertension[6] and deleterious lipid levels.[7]

CVD is a serious public health burden in terms of life-years lost, reduced quality of life, and medical costs.[8] Potentially low-cost interventions that can be successfully implemented population-wide and result in reductions in CVD risk factors should be a public health priority. Numerous behavioral interventions targeting CVD risk factor reduction through PA, diet, weight loss, and/or other lifestyle changes, either as primary or secondary outcomes, have been reported. Most have targeted multiple lifestyle factors including diet and PA,[9–25] whereas fewer have focused exclusively on PA.[26–30] Systematic reviews of randomized controlled trials have found that aerobic exercise significantly lowers blood pressure[6,31] and improves lipids and lipoproteins.[32,33]

Primary care facilities are a natural setting for delivering interventions to improve CVD risk factors. Primary care settings have the potential to reach large numbers of people, as nearly 87% of US adults see a health care professional at least one time a year, and nearly 25% have at least four visits a year.[34] Visits to a primary care facility offer a "teachable moment" in which behavior change can be discussed. Despite the appeal of behavioral interventions in primary care settings, a recent review concluded that lifestyle counseling interventions delivered in these settings have marginal benefit in changing CVD risk factors in low-risk patients.[35] Of the studies that included PA as a part of the lifestyle intervention in the review, three of six found small but significant benefits for blood pressure,[22,24,25] and one of four found small but significant benefits for cholesterol.[25]

The Activity Counseling Trial (ACT) was a 2-year multicenter randomized controlled trial delivered in primary care settings that evaluated the effects of three levels of PA counseling on cardiorespiratory fitness (fitness) and PA.[36,37] Secondary outcomes included the CVD risk factors of resting blood pressure, lipids, and lipoproteins. Primary outcomes have been reported elsewhere.[38] Briefly, women in the two intervention arms receiving physician advice plus counseling from a health educator had significantly greater improvements in fitness compared with the physician-advice-only comparison arm at 24 months. Differences in fitness for men did not differ across intervention arms; all three arms improved over the 24-month study period.[38] The purpose of this paper is to: 1) examine the effects of the ACT interventions on CVD risk factors, ie, systolic blood pressure (SBP) and diastolic blood pressure (DBP), lipoproteins (total cholesterol [TC], high-density lipoprotein cholesterol [HDL-C], LDL-C, the ratio of TC to HDL-C, and triglycerides; 2) examine whether changes in CVD risk factors differed according to baseline risk factor status (high versus normal);

3) examine whether changes in fitness were associated with changes in CVD risk factors; and 4) examine whether changes in weight explained associations between changes in fitness and changes in CVD risk factors.

Methods

Detailed descriptions of ACT have been published.[36–38] Participants were recruited over an 18-month period (1995–1997) from 10 primary care facilities, involving 51 physicians, four physician assistants, and one nurse practitioner.[38] Participants were inactive adults, aged 35–75 years, in stable health, planning and/or scheduled to see their primary care health professional during recruitment, able to read and write in English, independent in their daily living, and able to increase their PA levels.[37]

The primary care facilities used for recruitment were affiliated with three clinical centers: Stanford University, the University of Tennessee, and the Cooper Institute in conjunction with the University of Texas Southwestern Medical Center. The ACT coordinating center was Wake Forest University School of Medicine, and the project office was the National Heart, Lung, and Blood Institute.[38] The ACT study was approved yearly by each of the institutional review boards from the clinical and coordinating centers.

Intervention

After baseline assessments, participants were randomly assigned to one of three treatment arms that varied by level of counseling, intensity, and resource requirements: physician/health care provider advice (ie, optimal standard care), assistance, and counseling.[36] Social cognitive theory (SCT)[39] and the transtheoretical model (TTM)[40] guided the ACT intervention.[36] With the exception of physician advice, the intervention was delivered by ACT health educators.[38] All three arms were given the same PA goals, based on the national recommendations of 5 or more days of 30 minutes or more of moderate intensity PA[41] or 3 or more days of 30 minutes or more of vigorous intensity PA.[42]

Participants in the standard care or "advice" arm received brief counseling (2–4 minutes) from their primary care provider on the recommended amount of PA and were given standard written materials on PA guidelines from the ACT health educator.[36,38] Participants in this arm were invited to call the health educator with any questions regarding their PA program (eg, type or amount of PA); however, behavioral counseling was not provided.[36,38]

Participants randomized to the staff assistance intervention or "assistance" arm received the same provider advice and

educational materials as the advice arm, plus a 30–40 minute counseling session with a health educator and monthly theory-based, behavior change-oriented interactive mailed newsletters.[36,38] The interactive mail component was intended to increase cognitive and behavioral skills for increasing PA.[36,38] Each newsletter included a postage-paid mail-back card for reporting weekly PA, current goals, and barriers to PA. After receiving the mail-back card, health educators sent the participants feedback sheets addressing the specific barriers they encountered.[36,38] Participants in this arm also received an electronic pedometer and calendar to encourage self-monitoring, inexpensive incentives, and brief behavioral counseling from the health educators at each subsequent naturally occurring visit to his or her physician.[36,38]

Participants in the staff-counseling intervention or "counseling" arm received everything the advice and assistance arms received plus health educator-initiated telephone counseling biweekly for the first 6 weeks, then monthly for the remainder of the first year. During the second year, the health educator and participant decided together how frequent the subsequent counseling calls would be.[36,38] Weekly behavior change classes conducted by the health educators were also offered to participants in this intervention arm. The classes focused primarily on building the cognitive and behavioral skills needed to adopt and maintain PA.[36,38]

Clinical measures
Demographic variables
Participants reported their age, gender, race/ethnicity, current marital status, income, highest grade of school completed, and whether they were currently taking medications for hypertension or elevated cholesterol.[43]

Body mass index
Height to the nearest 1/10 centimeter and weight to the nearest 1/10 kilogram were measured by trained staff and body mass index (BMI) was calculated.

Lipids and lipoproteins
Blood samples were drawn after an overnight fast and analyzed in a central laboratory for TC, HDL-C, LDL-C (calculated from the Friedewald equation[44]), and triglycerides. The ratio of TC to HDL-C was calculated for analyses.

Blood pressure
After participants sat quietly for 5 minutes, resting SBP and DBP was measured three times using a standard mercury sphygmomanometer. The average of the second and third measures was used for statistical analyses.

Cardiorespiratory fitness
Fitness was assessed by measuring maximal oxygen uptake (VO_2 max, mL/kg/min) using a graded maximal exercise test on a treadmill at the baseline and 24-month visits. After participants warmed up with a brief walk at a 0% grade, the speed was increased until steady-state heart rate of 60% of age-predicted maximum or a rating of 11–13 on the Borg scale[45] of perceived exertion was maintained for 4 minutes. Then, treadmill grade was elevated 2% in 2-minute stages until the rate of perceived exertion (RPE) reached 17 or above, thereafter increasing the grade by 1% until the participant reached volitional fatigue or standard stopping criteria.[46]

Statistical analyses
The original study was powered to test outcomes for men and women separately.[37,38] Therefore, all analyses were stratified by sex. All statistical analyses were performed using SAS (version 9.2; SAS Institute, Cary, NC). Repeated measures ANOVA procedures (using SAS PROC MIXED) were used to examine change over time in SBP, DBP, TC, HDL-C, LDL-C, TC to HDL-C ratio, and triglycerides. Because Group × Time interactions revealed no significant differences in change over time between study arms on any of the CVD risk factors examined, this term was removed from all models, and the effects of time, independent of arm, were examined. All models controlled for arm, race/ethnicity, education, age, sex, baseline BMI, and clinical site. The same set of models for each outcome variable was repeated, adding medication intake as a time-varying covariate (blood pressure medication [yes/no] for SBP and DBP models; and high cholesterol medication [yes/no] for TC, HDL-C, LDL-C, TC to HDL-C ratio, and triglycerides models). Finally, Time × Baseline risk factor status interactions (high versus normal, except HDL-C, which was classified as low versus normal) examined whether changes in CVD risk factors differed according to baseline risk factor status. "High" was defined as the following: SBP $\geq$ 140, DBP $\geq$ 90, TC $\geq$ 240, TC to HDL-C ratio $\geq$5:1, LDL-C $\geq$160, and triglycerides $\geq$200, whereas "low" was defined as HDL-C $<$40 for men and $<$50 for women. Participants who reported being on blood pressure or high cholesterol medication at baseline were classified as "high" (or "low" for HDL-C) for the corresponding blood pressure and/or cholesterol analyses.

ANCOVA models (SAS PROC GLM) examined the relationship between changes in each of the secondary outcomes

and changes in fitness, independent of arm assignment. Because changes in weight may be related to changes in CVD risk factors and thus potentially confound fitness–CVD risk factor relationship, we also examined the relationship between changes in the secondary outcomes and changes in weight. To test the independent effects of each, both variables (ie, changes in fitness and weight) were entered simultaneously into the model. A separate model, controlling for the same covariates above, was conducted for each of the CVD risk factors.

Results

Participants were 479 men and 395 women with a mean age of 51.2 ± 9.7 years for women and 50.7 ± 9.6 years for men (Table 1). There were no differences between intervention arms on key demographic variables for women or men. At baseline, 36% of women and 34% of men were classified as hypertensive (SBP $\geq$ 140 mm Hg, DBP $\geq$ 90 mm Hg or taking antihypertensive medication) and 21% of women and 26% of men had hyperlipidemia (LDL-C $\geq$ 160 mg/dL or taking lipid-lowering medication). There were no differences between groups on any CVD risk factors at baseline for either gender (Table 2).

Changes in CVD risk factors: women

Table 2 shows the adjusted means for each CVD risk factor at baseline and 24 months for women. Results showed a significant increase in SBP ($P = 0.004$). There were no significant changes in DBP ($P = 0.83$), TC ($P = 0.45$), HDL-C ($P = 0.90$), LDL-C ($P = 0.42$), the TC to HDL-C ratio ($P = 0.90$), or triglycerides ($P = 0.99$). Models adjusting for medication intake did not significantly change the results for any of the risk factors (data not shown).

Table 3 shows whether changes in CVD risk factors differed by baseline risk factor status. Significant Time × Baseline risk factor status interactions were found for all CVD risk factors ($P < 0.0001$ for all). SBP significantly increased among participants with high SBP at baseline ($P = 0.01$) but not among those with normal blood pressure ($P = 0.13$). TC significantly decreased among participants with high TC at baseline ($P < 0.0001$), but significantly increased among participants with normal TC at baseline ($P = 0.04$). HDL-C significantly increased in participants with low HDL-C at baseline ($P = 0.01$), but did not change among those with normal baseline HDL-C ($P = 0.05$). There were significant decreases in LDL-C ($P < 0.0001$), the TC to HDL-C ratio ($P = 0.01$), and triglycerides ($P = 0.001$) among participants with high corresponding baseline levels, but not among participants with normal levels ($P = 0.07$, $P = 0.08$, and $P = 0.11$, respectively). Finally, although DBP was significantly different among those

Table 1 Baseline characteristics of men and women in the Activity Counseling Trial

	Women (n = 395)		Men (n = 479)	
	N	% or Mean ± SD	N	% or Mean ± SD
Age	395	51.2 ± 9.7	479	50.7 (9.6)
Race				
White	253	64.4	344	72.6
Black	121	30.8	96	20.3
Other	19	4.8	34	7.2
Education				
<High school graduate	33	8.4	14	2.9
High school graduate	61	15.4	30	6.3
Some college	158	40.0	87	18.2
College graduate	76	19.2	155	32.4
Postgraduate	67	17.0	193	40.3
Income (USD, per annum)				
<$30,000	135	35.6	56	11.9
$30,000 to <$50,000	91	24.0	61	13.0
$50,000 to <$75,000	63	16.6	97	20.6
$75,000 to <$100,000	40	10.6	85	18.1
$100,000+	50	13.2	172	36.5
Employment status				
Employed	275	69.8	40913	85.4
Unemployed	19	4.8	46	2.7
Retired	43	10.9	11	9.6
Homemaker	46	11.7	n/a	2.3
Other	11	2.8	n/a	n/a
Current smoker				
Yes	40	10.2	38	7.9
No	353	89.8	441	92.1
BMI (kg/m^2)	389	30.4 ± 7.2	475	28.9 ± 5.2
VO$_2$ max (mL/kg/min)	395	20.7 ± 5.4	479	28.8 ± 6.5
Hypertension				
Yes	141	35.7	163	34.0
No	254	64.3	316	66.0
Hyperlipidemia				
Yes	80	21.2	120	25.8
No	297	78.8	345	74.2

Abbreviations: BMI, body mass index; SD, standard deviation; n/a, not applicable; VO$_2$ max, maximal oxygen uptake.

with high and normal baseline levels, neither group changed significantly over time.

Changes in CVD risk factors: men

Table 2 shows the adjusted means for each CVD risk factor examined at baseline and 24 months for men. Results showed a significant decrease in DBP ($P = 0.0002$), TC ($P < 0.0001$), LDL-C ($P < 0.0001$), the TC to HDL-C ratio ($P = 0.01$), and

Table 2 Cardiovascular disease risk factors at each assessment time for women and men

	Women			Men		
	Mean (SE)	% change	*P*-value	Mean (SE)	% change	*P*-value
SBP, mm Hg						
Baseline	117.2 (1.8)	1.6	0.004	122.6 (1.1)	−0.16	0.70
24 months	119.1 (1.8)			122.4 (1.1)		
DBP, mm Hg						
Baseline	74.4 (1.1)	0.13	0.83	80.7 (0.69)	−1.6	0.002
24 months	74.5 (1.1)			79.4 (0.70)		
TC, mg/dL						
Baseline	194.9 (5.0)	−0.62	0.45	204.3 (3.2)	−4.4	<0.0001
24 months	193.7 (5.1)			195.6 (3.3)		
HDL-C, mg/dL						
Baseline	50.9 (1.9)	0.0	0.90	41.7 (0.91)	0.24	0.78
24 months	50.9 (1.9)			41.8 (0.92)		
LDL-C, mg/dL						
Baseline	121.2 (4.6)	−1.0	0.42	132.5 (2.9)	−5.2	<0.0001
24 months	120.0 (4.6)			126.0 (2.9)		
TC/HDL-C						
Baseline	4.2 (0.17)	0.0	0.90	5.2 (0.14)	−4.0	0.005
24 months	4.2 (0.18)			5.0 (0.14)		
Triglycerides, mg/dL						
Baseline	114.2 (9.2)	0.09	0.99	150.3 (9.1)	−8.1	0.01
24 months	114.1 (9.3)			139.1 (9.2)		

Note: All models controlled for group, race, education, age, sex, and clinical site.
Abbreviations: DBP, diastolic blood pressure; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; SBP, systolic blood pressure; SE, standard error; TC, total cholesterol.

triglycerides ($P = 0.01$). There were no significant changes in SBP ($P = 0.70$) or HDL-C ($P = 0.78$). Models adjusting for medication intake did not significantly change the results for any of the risk factors (data not shown).

Table 3 shows whether changes in CVD risk factors differed by baseline risk factor status. Significant Time × Baseline risk factor status interactions were found for all CVD risk factors ($P < 0.0001$ for all). There were significant decreases in DBP ($P < 0.0001$), TC ($P < 0.0001$), LDL-C ($P < 0.0001$), the TC to HDL-C ratio ($P < 0.0001$), and triglycerides ($P < 0.0001$) among participants with high corresponding baseline levels but not among participants with normal levels ($P = 0.08$, $P = 0.09$, $P = 0.64$, $P = 0.22$, $P = 0.62$, respectively). HDL-C significantly increased in participants with low HDL-C at baseline ($P = 0.04$) but did not change among those with normal baseline HDL-C ($P = 0.06$). Finally, although SBP was significantly different among those with high and normal baseline levels, neither group significantly changed over time.

Associations between changes in fitness, weight, and CVD risk factors: women

There were a number of significant associations between changes in CVD risk factors and changes in fitness and weight in women participating in ACT (Table 4). An increase in fitness from baseline to 24 months was associated with a significant decrease in TC ($P = 0.01$) and triglycerides ($P = 0.03$) from baseline to 24 months. A decrease in weight from baseline to 24 months was associated with a decrease in SBP ($P = 0.002$), DBP ($P = 0.0003$), the TC to HDL-C ratio ($P = 0.01$), and triglycerides ($P = 0.003$), and an increase in HDL-C ($P < 0.0001$) from baseline to 24 months. When changes in fitness and changes in weight were entered simultaneously into the model, only one result changed: an increase in fitness was no longer associated with a decrease in triglycerides after controlling for change in weight ($P = 0.17$).

Associations between changes in fitness, weight, and CVD risk factors: men

There were a number of significant associations between changes in CVD risk factors and changes in fitness and weight in men participating in the ACT (Table 4). An increase in fitness from baseline to 24 months was associated with a significant decrease in the TC to HDL-C ratio ($P = 0.004$) and triglycerides ($P = 0.003$), and an increase in HDL-C ($P = 0.003$) from baseline to 24 months. There was also a borderline significant relationship in the expected direction for DBP ($P = 0.06$). A decrease in weight from baseline to

Table 3 Cardiovascular disease risk factors for women and men at baseline and 24 months, by baseline risk factor level

	Women				Men			
	Baseline	24 months			Baseline	24 months		
	Mean (SE)	Mean (SE)	% change	P-value Interaction	Mean (SE)	Mean (SE)	% change	P-value Interaction
SBP, mm Hg								
Normal	113.9 (1.8)	115.1 (1.8)	1.1	<0.0001	119.3 (1.0)	119.0 (1.1)	−0.25	<0.0001
High	121.1 (1.9)	124.3 (2.0)[a]	2.6		131.4 (1.3)	131.7 (1.4)	0.23	
DBP, mm Hg								
Normal	72.6 (1.1)	72.5 (1.1)	−0.14	<0.0001	78.0 (0.69)	77.4 (0.70)	−0.78	<0.0001
High	76.4 (1.1)	76.9 (1.2)	0.10		86.0 (0.83)	83.5 (0.86)[a]	−3.0	
TC, mg/dL								
Normal	186.2 (4.3)	189.5 (4.4)[a]	1.8	<0.0001	193.7 (2.9)	190.8 (3.0)	−1.5	<0.0001
High	240.7 (5.4)	223.5 (5.6)[a]	−7.7		245.5 (3.9)	217.2 (4.1)[a]	−13.0	
HDL-C, mg/dL								
Normal	60.0 (1.5)	58.5 (1.6)	−2.6	<0.0001	48.5 (0.81)	47.4 (0.84)	−2.3	<0.0001
Low	41.0 (1.5)	43.0 (1.6)[a]	4.9		35.0 (0.81)	36.0 (0.83)[a]	2.9	
LDL-C, mg/dL								
Normal	113.5 (4.0)	116.3 (4.0)	2.5	<0.0001	120.2 (2.6)	119.5 (2.7)	0.59	<0.0001
High	162.7 (5.0)	147.1 (5.1)[a]	−10.6		165.0 (3.3)	142.2 (3.4)[a]	−16.0	
TC/HDL-C								
Normal	3.6 (0.14)	3.7 (0.15)	2.8	<0.0001	4.0 (0.12)	4.1 (0.13)	2.5	<0.0001
High	5.5 (0.16)	5.2 (0.17)[a]	5.8		6.3 (0.12)	5.9 (0.12)[a]	−6.8	
Triglycerides, mg/dL								
Normal	97.4 (7.6)	103.0 (7.8)	5.7	<0.0001	110.1 (7.4)	112.6 (7.7)	2.3	<0.0001
High	214.4 (10.3)	184.2 (11.1)[a]	−16.4		265.7 (9.5)	220.6 (9.9)[a]	−20.4	

Notes: [a]P < 0.05; All models controlled for group, race, education, age, sex, and clinical site.
Abbreviations: DBP, diastolic blood pressure; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; SBP, systolic blood pressure; SE, standard error; TC, total cholesterol.

24 months was associated with a decrease in SBP ($P = 0.003$), DBP ($P < 0.0001$), TC ($P < 0.0001$), the TC to HDL-C ratio ($P < 0.0001$), and triglycerides ($P \leq 0.0001$), and an increase in HDL-C ($P = 0.008$) from baseline to 24 months. There were no other significant relationships for any other CVD risk factors examined. When changes in fitness and weight were entered simultaneously into the model, results did not change for weight, with the exception of HDL-C, which was no longer related to decreases in weight ($P = 0.09$). Although HDL-C ($P = 0.04$) remained significant, changes in the TC to HDL-C ratio ($P = 0.20$) and triglycerides ($P = 0.19$) were no longer associated with changes in fitness. The borderline relationship of fitness to DBP also disappeared ($P = 0.60$).

Discussion

Intervention approaches that can be successfully disseminated and result in meaningful reductions in CVD risk factors are needed. This study evaluated the effects of three levels of a PA intervention delivered in primary care settings on CVD risk factors. Several risk factor improvements were achieved, irrespective of intervention assignment, for men and women with unfavorable baseline levels of CVD risk factors, but not for those with normal baseline levels.

The lack of significant differences between intervention arms over time should not be interpreted as unsuccessful intervention approaches. Although the advice arm was considered the "control arm", there really was not a true control arm in ACT. All participants (including those in the advice arm) received 2–4 minutes of PA counseling from a physician/health care provider in addition to written materials about PA from a health educator. Although physician advice about PA is recommended as part of standard practice,[47] a majority of physicians are not counseling patients on PA.[48] Furthermore, all participants completed extensive assessments throughout the course of the trial, including repeated maximal exercise tests, which could have influenced motivation to change behavior.[49] Finally, many participants in ACT were recruited through physician-signed letters which could have also provided additional behavioral motivation in all arms.

Significant improvements in CVD risk factors were seen in both men and women who had high (or low for HDL-C) baseline levels of CVD risk factors, with the exception of SBP, which did not change in men or women, and DBP, which only improved in men. However, none of the CVD risk factors improved among participants with normal baseline

Table 4 Relationship between changes in CVD risk factors and 1) changes in fitness, 2) changes in weight, and 3) changes in fitness + weight

	Women				Men			
	Model I		Model II		Model I		Model II	
	Estimate (SE)	*P*-value	Estimate (SE)	*P*-value	Estimate (SE)	*P*-value	Estimate (SE)	*P*-value
SBP, mm Hg								
Δ Fitness	−0.12 (0.22)	0.60	0.10 (0.23)	0.67	−0.14 (0.15)	0.33	0.03 (0.15)	0.87
Δ Weight	2.9 (0.09)	0.002	0.32 (0.10)	0.002	0.35 (0.12)	0.003	0.34 (0.13)	0.008
DBP, mm Hg								
Δ Fitness	−0.12 (0.12)	0.32	0.01 (0.13)	0.96	−0.17 (0.09)	0.06	−0.05 (0.09)	0.60
Δ Weight	0.18 (0.05)	0.0003	0.20 (0.06)	0.0004	0.28 (0.07)	<0.0001	0.26 (0.08)	0.0008
TC, mg/dL								
Δ Fitness	−1.22 (0.47)	0.01	−1.09 (0.50)	0.03	−0.72 (0.42)	0.08	−0.22 (0.44)	0.62
Δ Weight	0.27 (0.21)	0.20	0.24 (0.22)	0.28	1.45 (0.33)	<0.0001	1.40 (0.37)	0.0002
HDL-C, mg/dL								
Δ Fitness	0.03 (0.19)	0.88	−0.22 (0.19)	0.25	0.31 (0.10)	0.003	0.24 (0.11)	0.04
Δ Weight	−0.32 (0.08)	<0.0001	−0.37 (0.09)	<0.0001	−0.22 (0.08)	0.008	−0.16 (0.09)	0.09
LDL-C, mg/dL								
Δ Fitness	−0.81 (0.45)	0.08	−0.54 (0.48)	0.26	−0.28 (0.39)	0.48	−0.11 (0.42)	0.80
Δ Weight	0.36 (0.20)	0.08	0.42 (0.22)	0.05	0.50 (0.32)	0.11	0.51 (0.35)	0.15
TC/HDL-C								
Δ Fitness	−0.03 (0.02)	0.13	−0.01 (0.02)	0.50	−0.05 (0.02)	0.004	−0.03 (0.02)	0.20
Δ Weight	0.02 (0.01)	0.01	0.02 (0.01)	0.01	0.08 (0.01)	0.0001	0.07 (0.02)	<0.0001
Triglycerides, mg/dL								
Δ Fitness	−2.23 (1.04)	0.03	−1.51 (1.09)	0.17	−3.69 (1.22)	0.003	−1.65 (1.27)	0.19
Δ Weight	1.38 (0.46)	0.003	1.18 (0.49)	0.02	5.88 (0.93)	<0.0001	5.19 (1.05)	<0.0001

Notes: All models controlled for group, race, education, age, sex, and clinical site. Model I tested the effects of Δ Fitness and Δ Weight separately. Model II entered Δ Fitness and Δ Weight in the model simultaneously, testing the independent effects of each.
Abbreviations: DBP, diastolic blood pressure; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; SBP, systolic blood pressure; SE, standard error; TC, total cholesterol.

levels. These results are not surprising, as participants with normal risk factors had less room for improvement. The significant improvements in participants with unfavorable baseline levels of risk factors are notable, as these individuals have the greatest need for meaningful reductions in risk factors and thus should be targeted in behavioral interventions focusing on CVD risk reduction.

DBP significantly decreased in men with high DBP at baseline. Although modest at the individual level (decrease of 2.5 mm Hg), this change should be interpreted within a public health context. A 2 mm Hg reduction in DBP applied across the population as a whole would reduce the prevalence of hypertension by 17%, and reduce the incidence of coronary heart disease (CHD) by 6% and incidence of stroke by 15%.[50] The significant decreases in LDL-C, TC, triglycerides, and the TC to HDL-ratio, and the significant increase in HDL-C among men and women with high levels at baseline, are also encouraging. Adjusted levels of LDL-C decreased ~11% in women and ~16% in men, TC decreased ~8% in women and ~13% in men, triglycerides decreased ~16% in women and ~20% in men, and the TC

to HDL-ratio decreased ~5% in women and ~7% in men, whereas HDL-C improved ~5% in women and ~3% in men. These changes are important and meaningful, as a 1% decrease in LDL-C is associated with a 1% reduction in the risk for CHD,[51] whereas a 1% decrease in TC is associated with a 2% reduction in CHD risk.[51] Improvements of this magnitude across the 21% of adults who have high LDL-C[4] and the 29% who have hypertension (≥140/90 mm Hg)[5] would produce powerful public health benefit.

Results from other home-based and/or lifestyle PA intervention studies have found mixed results on CVD risk factors. For example, a study by King et al[29] examining the effects of group- and home-based exercise programs on CVD risk factors found that although no effect was found at 1 year, there was a significant increase in HDL-C after 2 years among participants in two telephone-assisted home-based exercise training programs. However, there were no effects at either time point on TC, LDL-C, triglycerides, or blood pressure in this generally normotensive and nonhyperlipidemic sample of middle-aged adults. Dunn et al[52] found significant decreases in SBP, DBP, TC, the TC to HDL-C

ratio, and triglycerides, but not in LDL-C and HDL-C at 6 months among middle-aged participants in a lifestyle PA intervention group. However, SBP and DBP were the only risk factor reductions maintained at 24 months.[26] Two other studies delivered in general practice settings by an exercise specialist[28] and a general practitioner and exercise specialist[30] found significant within-group changes in CVD risk factors. However, differences between the intervention and control groups were not significant. Halbert et al[28] found significant decreases in SBP and DBP in the intervention but not control group, whereas Elley et al[30] found a decrease in TC, LDL-C, and triglycerides in both the intervention and control group, but no effects on blood pressure or HDL-C.

Changes in several CVD risk factors were associated with changes in fitness and weight. However, almost all of the significant relationships for fitness disappeared after controlling for weight change. The exceptions were for HDL-C (men) and TC (women), which remained independently associated with changes in fitness. An observational study by Sternfeld et al[53] also found significant associations between changes in TC, HDL-C, LDL-C, and triglycerides and changes in fitness and weight over a 7-year period. When examining the independent effects of fitness, similar to the present results for men, HDL-C was the only risk factor that remained significant. Results from these studies suggest that much of the association between changes in fitness and lipids is accounted for by changes in weight.[53] It is unclear whether weight change confounds the relationship between changes in fitness and CVD risk factors or if it is part of the pathway by which fitness and weight work together to influence CVD risk factors.[53] However, the independent effects of fitness on HDL-C, and perhaps on TC, suggest that confounding alone may not explain these complex relationships.

This study has a number of strengths including the objective measures of fitness, blood pressure, lipids, and lipoproteins. The large sample size also allowed gender-specific analyses. We also recognize our study limitations. The sample was predominantly highly educated and affluent, and over 70% of participants were White. Therefore, the study results may not generalize to other populations. Finally, changes in the dosage of blood pressure and cholesterol medications were not captured at the 24-month follow-up visit. Additional analyses excluding individuals on medication were conducted, and with a few exceptions, the results did not change. These findings suggest that changes in medication did not produce the improvements in CVD risk factors.

Interventions that can be implemented nationwide and that result in meaningful population-wide changes in CVD risk factors are needed. To overcome the challenges and barriers associated with behavioral interventions delivered by physicians in primary care settings, intervention protocols need to be parsimonious and efficient. Improvements in lipids from the ACT interventions could reduce the risk of CHD in people with already high levels of lipids by 16%–26% in men and 11%–16% in women. From a public health perspective, these results are promising, as asking physicians to briefly counsel patients on PA during each visit may be realistic.[54] Although significant improvements in CVD risk factors were found only among those with at-risk levels, it is important to note that PA provides other cardiovascular benefits beyond improvements in risk factor markers (ie, blood pressure, lipids), as well as mental health benefits. An innovative initiative launched by the American College of Sports Medicine and the American Medical Association, called Exercise is Medicine™, is encouraging primary care physicians, as well as other health professionals, to include regular PA in treatment plans for patients.[55] This initiative recognizes the importance of regular PA and calls on health care providers to treat PA as a "vital sign", which will result in the assessment and recording of PA at every clinic visit. The results from the present study provide support for the potential significance and success of such endeavors, particularly among individuals who may be in most need of changes.

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Disclosure

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