

# Multiple Behavior Changes in Diet and Activity

## A Randomized Controlled Trial Using Mobile Technology

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**Background:** Many patients exhibit multiple chronic disease risk behaviors. Research provides little information about advice that can maximize simultaneous health behavior changes.

**Methods:** To test which combination of diet and activity advice maximizes healthy change, we randomized 204 adults with elevated saturated fat and low fruit and vegetable intake, high sedentary leisure time, and low physical activity to 1 of 4 treatments: increase fruit/vegetable intake and physical activity, decrease fat and sedentary leisure, decrease fat and increase physical activity, and increase fruit/vegetable intake and decrease sedentary leisure. Treatments provided 3 weeks of remote coaching supported by mobile decision support technology and financial incentives. During treatment, incentives were contingent on using the mobile device to self-monitor and attain behavioral targets; during follow-up, incentives were contingent only on recording. The outcome was standardized, composite improvement on the 4 diet and activity behaviors at the end of treatment and at 5-month follow-up.

**Results:** Of the 204 individuals randomized, 200 (98.0%) completed follow-up. The increase fruits/vegetables and decrease sedentary leisure treatments improved more than the other 3 treatments ( $P < .001$ ). Specifically, daily fruit/vegetable intake increased from 1.2 servings to 5.5 servings, sedentary leisure decreased from 219.2 minutes to 89.3 minutes, and saturated fat decreased from 12.0% to 9.5% of calories consumed. Differences between treatment groups were maintained through follow-up. Traditional dieting (decrease fat and increase physical activity) improved less than the other 3 treatments ( $P < .001$ ).

**Conclusions:** Remote coaching supported by mobile technology and financial incentives holds promise to improve diet and activity. Targeting fruits/vegetables and sedentary leisure together maximizes overall adoption and maintenance of multiple healthy behavior changes.

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**N**ONADHERENCE WITH LIFESTYLE change advice is cited as a major barrier to effective preventive care.<sup>1,2</sup> Many physicians express skepticism that patients will change unhealthy behaviors; they also report lack of time and training to counsel patients effectively.<sup>3,4</sup>

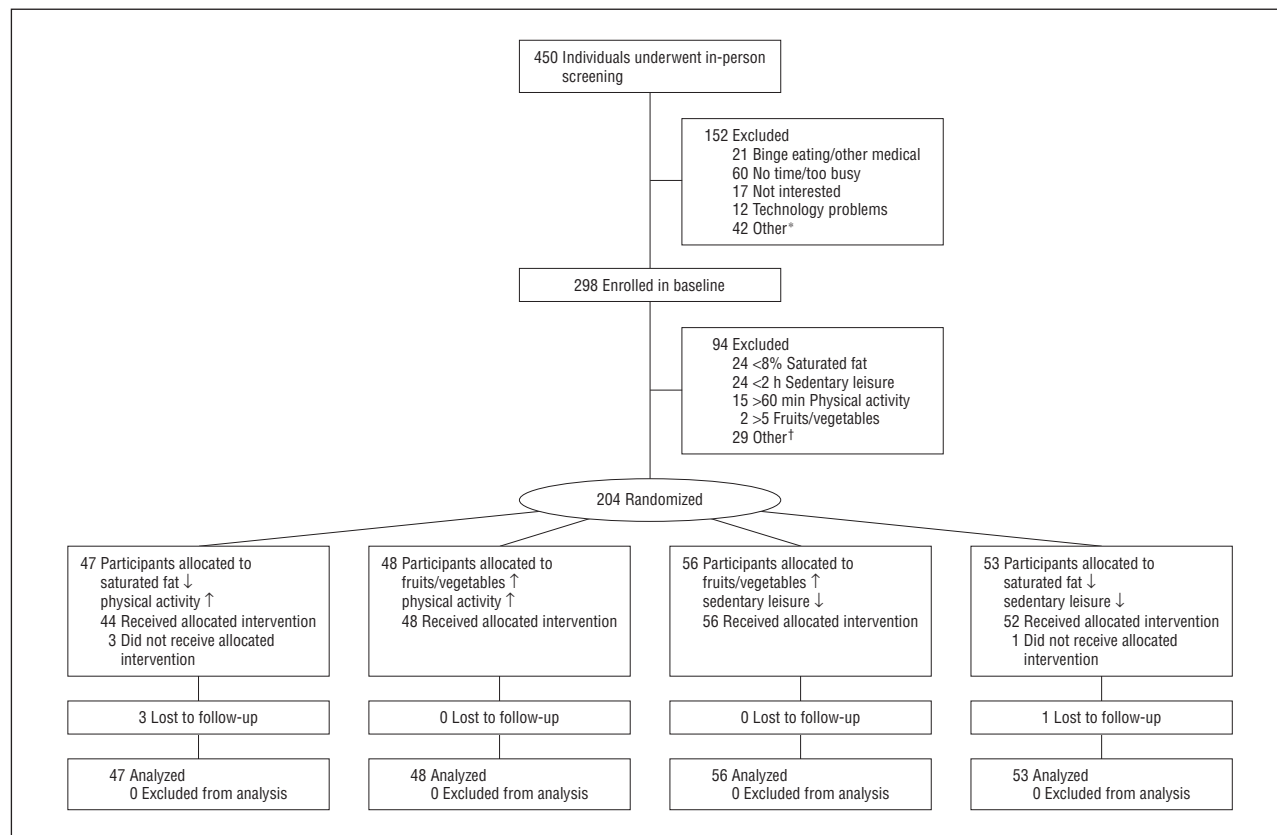
Poor-quality diet and inactivity are well-established behavioral risk factors for cardiovascular disease, cancer, and diabetes mellitus.<sup>5-8</sup> Although healthy lifestyle changes can reduce morbidity and premature mortality,<sup>9-12</sup> fewer than 25% of US adults meet the dietary guidelines,<sup>13</sup> and 25% report no leisure-time physical activity.<sup>14</sup> Suboptimal diet and a sedentary behavior pattern tend to cluster as risk behaviors,<sup>15-18</sup> heightening disease risk<sup>19</sup> and creating an opportunity to intervene comprehensively, efficiently, and, perhaps, even synergistically on more than 1 risk behavior simultaneously. However, data

are sparse regarding how to change multiple lifestyle behaviors simultaneously, especially when in-person contact time is limited, as in the medical encounter.

### See Invited Commentary at end of article

Increasingly, patients use mobile devices to manage activities across life domains, including health.<sup>20,21</sup> This study's interventions leveraged handheld technology to create efficient interventions that make self-monitoring more convenient, extend decision support into life contexts where lifestyle choices are made,<sup>21,22</sup> and convey time-stamped behavioral data to paraprofessionals who provide coaching remotely. Participants received a handheld device and financial incentives initially to adopt recommended changes and subsequently to report behavior intermittently.

We designed the Make Better Choices trial to determine which combination of advice



**Figure 1.** CONSORT (Consolidated Standards of Reporting Trials) flow diagram. \*Other at screening includes no personal computer/landline, substance abuse, required but did not receive physician approval for blood pressure, and ineligible due to recent lifestyle change. †Other at baseline includes incomplete data during baseline recording, unreliable recording/compliance/communication, and required but did not receive physician approval for blood pressure. † Indicates increase; ↓, decrease.

to change 1 dietary behavior (high saturated fat or low fruit and vegetable intake) and 1 activity behavior (high sedentary leisure or low physical activity) would maximize healthy diet and activity change during treatment and follow-up. Per behavioral choice theory,<sup>23,24</sup> we predicted that increasing intake of fruits/vegetables and decreasing sedentary leisure would maximize healthy change by fostering healthy substitution (of fruits/vegetables for fat and physical activity for sedentary leisure) and complementary behavior change (decreased fat accompanying decreased sedentary leisure). We also tested 2 alternative predictions about which treatment would maximize healthy change: traditional dieting (decrease fat and increase physical activity) because of its familiarity or increase healthy behaviors (increase fruits/vegetables and physical activity) because it requires the least inhibition of rewarding behaviors.<sup>24</sup>

## METHODS

The study design and methods are discussed in detail elsewhere<sup>24</sup> and are described briefly herein.

### STUDY SAMPLE

Adults aged 21 to 60 years were recruited through community advertisements. Eligible individuals were required to report all of the following: (1) intake of fewer than 5 fruits/vegetables daily,<sup>25,26</sup> (2) greater than 8% caloric intake from saturated fat, (3) less than 60 min/d of moderate or vigorous physical activ-

ity, and (4) greater than 90 min/d of sedentary leisure (television, movies, recreational Internet use, and video games).

**Figure 1** diagrams participant flow through the trial. All the procedures were approved by the institutional review boards of the University of Illinois at Chicago and Northwestern University.

### 2-WEEK BASELINE PHASE (AND FINAL ELIGIBILITY SCREENING)

Candidates who self-reported all 4 risk behaviors were screened by a bachelor's-level research assistant (coach: J.V., M.S., or A.D.). The coach trained participants to estimate accurately and to use a handheld device to record and upload dietary intake, moderate- to vigorous-intensity physical activity, and targeted sedentary leisure. During the 2-week baseline phase, participants wore an accelerometer, recorded diet and activity on the handheld device, and uploaded data daily.

### RANDOMIZATION

Candidates who displayed all 4 risk behaviors, as evidenced by handheld device and accelerometer data, were randomized (stratified by sex) using a computer-generated sequence of randomly permuted blocks.

### INTERVENTION (BEHAVIORAL TREATMENT) PHASE

Coaches tailored behavioral strategies based on participants' baseline data. For example, those asked to decrease fat were shown

10 foods that supplied their greatest saturated fat grams and were coached to reduce portion size or number for those foods. For the first week of treatment, daily goals were set midway between the baseline behavior and the ultimate daily goal. Beginning the second treatment week, full goals were set for the 2 targeted behaviors to which the participant was randomized: 5 fruit/vegetable servings, saturated fat intake less than 8% of calories, physical activity of at least 60 min/d, or sedentary leisure less than 90 min/d. Participants were expected to reach their behavioral targets during treatment week 2 and to maintain them during week 3. During the 3 treatment weeks, participants uploaded data daily and communicated as needed with their coaches via telephone or e-mail, per preference, to overcome challenges. Participants could earn a \$175 incentive for meeting the goals for both targeted behaviors during the treatment phase.

### FOLLOW-UP PHASE

To explore the potential for maintenance of healthy behavior changes, the study included a 20-week follow-up. Immediately after the treatment period, participants were informed that attainment of diet and activity targets was no longer required and that payment was now contingent solely on recording and transmitting handheld device data on a predetermined schedule. Recording was required daily for the first week after treatment, for 3 consecutive days in posttreatment weeks 2 and 3, biweekly for the next 6 weeks, and then monthly until final follow-up. Participants could earn incrementally larger financial incentives (from \$30 to \$80) for uploading data during consecutive follow-ups. All the incentives were received at the end of follow-up.

### HANDHELD TOOL

Participants used a personal digital assistant to record and self-regulate their targeted behaviors. They were advised to carry the device and record immediately after executing a behavior. During treatment and follow-up, the handheld device displayed 2 decision support feedback “thermometers”: 1 for diet (fruits/vegetables or fat) and 1 for activity (physical activity or sedentary leisure) (eFigure and eAppendix; <http://www.archinternmed.com>). Once activated, goal thermometers were continually updated in response to data entry. They also enabled participants to look up the potential impact of a food or activity choice.

### MEASURES

Outcomes were assessed by daily self-report recordings on the handheld device. Fat and fruit/vegetable consumption were measured from dietary intake recordings. To prevent superfluous calories (eg, in sweetened beverages) from inflating the fat gram allowance, the saturated fat goal for those randomized to decrease fat was determined using the Harris-Benedict equation<sup>27</sup> to estimate calories needed to maintain weight. Minutes of physical and sedentary activity were measured cumulatively by an end-of-day 24-hour activity log in which participants accounted for every 15-minute block of each day. Previous studies have established the validity of self-report diet and activity assessments administered via a mobile device.<sup>28-32</sup> To further encourage honest recording, we implemented a validated bogus pipeline protocol<sup>33</sup> whereby participants submitted grocery receipts, accelerometer data, and urine samples that they believed would be used to evaluate their self-reports.

## COMPOSITE DIET-ACTIVITY IMPROVEMENT SCORE

Rather than measure only single behaviors, we assessed simultaneous overall change on all 4 behaviors. To place the 4 behaviors (fruits/vegetables, fat, physical activity, and sedentary leisure) on a common scale to quantify overall change, we developed a “Composite Diet-Activity Improvement Score” that weighted each behavior equally. We transformed all the variables to better approximate normality by using square root transformation for the count outcomes (fruits/vegetables, physical activity, and sedentary leisure) and arc sine transformation for the percentage outcome (fat).<sup>34</sup> Then we standardized each individual health behavior using a modified *z* score (where 1 U represents a 1-SD change), with higher values representing greater healthy lifestyle improvement. To reflect improvement relative to baseline, we standardized *z* scores for time points after baseline relative to the overall baseline distribution. We calculated the mean of all 4 individual *z* scores at each time point, as recommended,<sup>35</sup> to derive a composite index that expressed each participant’s overall healthy change across multiple diet and activity behaviors.

### STATISTICAL ANALYSIS

The primary analytic aim was to determine which behavioral treatment maximizes initiation of healthy diet and activity changes, measured as improvement from baseline through the treatment phase. The secondary aim was to examine maintenance of change on the Composite Diet-Activity Improvement Score. A sample size of 200 (50 per treatment) was projected to yield power of 0.85 to detect a 0.5-SD difference in diet and activity improvement between treatments.

Statistical analyses were performed using a commercially available software program (SAS, version 9.2; SAS Institute, Inc). Study hypotheses were tested using 3 a priori planned contrasts comparing the predicted best treatment with all others combined: (1) decrease fat and increase physical activity vs others combined, (2) increase fruit/vegetable intake and physical activity vs others combined, and (3) increase fruit/vegetable intake and decrease sedentary vs others combined. The analyses used a linear mixed model for longitudinal data,<sup>36</sup> with the Composite Diet-Activity Improvement Score as the dependent variable. For the within-participants factor of time (baseline, intervention week 1 and weeks 2 and 3, and follow-ups 1-8), we tested 2 comparisons for the intervention phase (intervention week 1 vs baseline and intervention weeks 2 and 3 vs week 1) and 3 for the follow-up phase (an average of all follow-ups vs the final treatment phase time point and linear and quadratic trends during follow-up). These 5 time comparisons are included in all the analyses. We also created interaction terms for each hypothesis by each time contrast. Inferences focused on treatment × time interactions, which compare the difference in behavior change over time between treatments, specifically testing for the components of the treatment × time interaction in a hierarchical manner (ie, treatment × follow-up first, then treatment × intervention phase). For the variance-covariance structure of the longitudinal data, we used a heterogeneous Toeplitz structure<sup>36</sup> that allowed the variances to vary across time and the correlations to vary across time lags. All the analyses were performed on an intention-to-treat basis and included sex as a covariate. Across the 11 time points, the proportion of missing data ranged from 4% to 11%.

We used separate mixed-effects regression models to predict each participant’s change from baseline through the treatment phase for each of the 4 behaviors. We then correlated these

**Table 1. Baseline Characteristics of Participants Assigned to Each Treatment Group**

Characteristic	Total (N = 204)	Fruits/Vegetables <sup>↑</sup> and Physical Activity <sup>↑</sup> (n = 48)	Saturated Fat <sup>↓</sup> and Sedentary Leisure <sup>↓</sup> (n = 53)	Fruits/Vegetables <sup>↑</sup> and Sedentary Leisure <sup>↓</sup> (n = 56)	Saturated Fat <sup>↓</sup> and Physical Activity <sup>↑</sup> (n = 47)	Test	P Value (by Treatment)
Age, mean (SD), y	32.8 (11.0)	33.4 (10.8)	30.8 (10.8)	35.0 (12.1)	31.9 (9.7)	F = 1.563	.20
BMI, mean (SD)	28.3 (7.3)	28.6 (7.0)	27.0 (6.6)	28.3 (6.1)	29.4 (9.3)	F = 0.864	.46
Sex, No. (%)						χ <sup>2</sup> = 2.05	.56
Male	48 (23.5)	14 (29.2)	12 (22.6)	14 (25.0)	8 (17.0)		
Female	156 (76.5)	34 (70.8)	41 (77.4)	42 (75.0)	39 (83.0)		
Ethnicity, No. (%)						χ <sup>2</sup> = 10.93	.54
White	109 (53.4)	22 (45.8)	32 (60.4)	33 (58.9)	22 (46.8)		
Black	47 (23.0)	15 (31.3)	6 (11.3)	12 (21.4)	14 (29.8)		
Hispanic/Latino	18 (8.8)	3 (6.3)	5 (9.4)	6 (10.7)	4 (8.5)		
Asian	23 (11.3)	7 (14.6)	7 (13.2)	4 (7.1)	5 (10.6)		
Other or multiple	7 (3.5)	1 (2.1)	3 (5.7)	1 (1.8)	2 (4.3)		
Education, No. (%)						χ <sup>2</sup> = 3.14	.37
College degree	151 (74.0)	31 (64.6)	41 (77.4)	44 (78.6)	35 (74.5)		
No college degree	53 (26.0)	17 (35.4)	12 (22.6)	12 (21.4)	12 (25.5)		

Abbreviation: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared). ↑ Indicates increase; ↓, decrease.

4 individual change estimates to examine whether changes in targeted behaviors were correlated with changes in untargeted behaviors.

## RESULTS

### STUDY SAMPLE

The final sample of 204 adults included 48 men, 46.6% with nonwhite race/ethnicity, 26.0% with no more than a high school education, and a mean (SD) age of 33 (11) years. Demographic information is summarized in **Table 1**. Except for 1 individual, all the participants attained the behavioral targets; most did so promptly. The median time taken to achieve consumption of 5 fruits/vegetables was 9 days (ie, 2 days after the 5 fruits/vegetables goal was set). The median time taken to attain the sedentary, fat, and physical activity targets was 8 days (ie, 1 day after the targeted amount was set).

### TREATMENT EFFECTS ON COMPOSITE DIET-ACTIVITY IMPROVEMENT SCORES

The treatment × intervention phase interaction was highly significant (χ<sub>6</sub><sup>2</sup> = 38.1, P < .001), indicating that the treatment groups differed significantly on the Composite Diet-Activity Improvement Score. Furthermore, this treatment effect remained significant throughout the subsequent follow-up period (observed means are graphed in **Figure 2A**).

The increase fruits/vegetables and decrease sedentary leisure treatment increased Composite Diet-Activity Improvement Scores more than the alternative treatments in the first week of intervention (t<sub>383</sub> = 3.16, P = .002). The superiority of the increase fruits/vegetables and decrease sedentary leisure treatment, evident after 1 week, was maintained through the end of the 3-week treatment period and through follow-up week 20 (Figure 2B).

The decrease fat and increase physical activity treatment decreased Composite Diet-Activity Improvement Scores compared with other treatments in the first week of intervention (t<sub>382</sub> = -2.17, P = .03), a disadvantage that persisted through the end of treatment and follow-up.

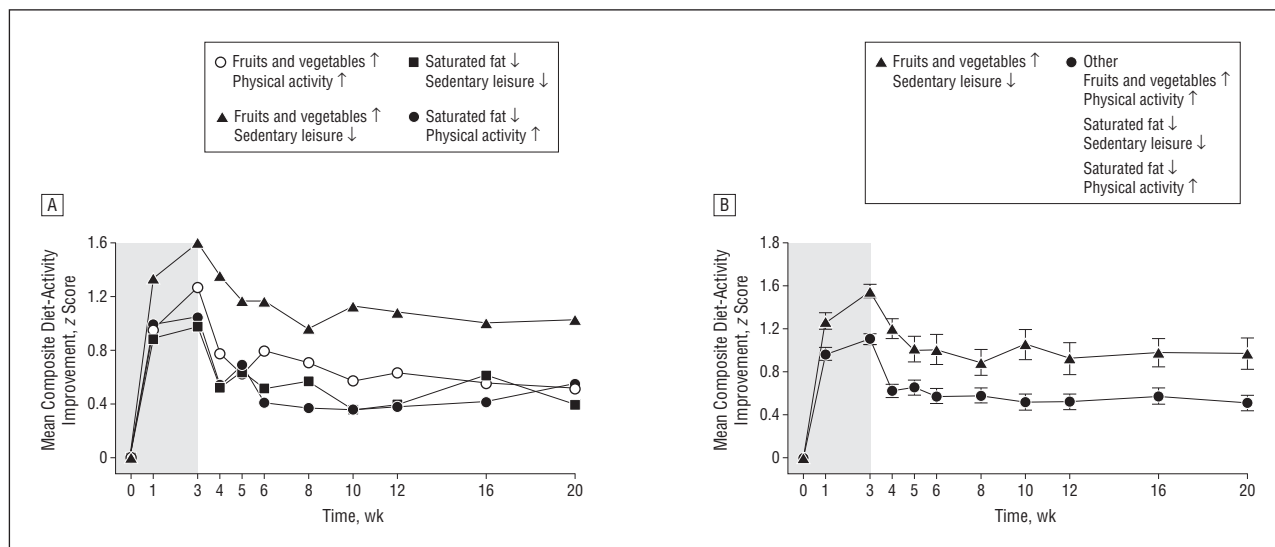
### TREATMENT EFFECTS ON INDIVIDUAL DIET AND ACTIVITY BEHAVIORS

**Figure 3** shows the effect of the increase fruits/vegetables and decrease sedentary leisure treatment on standardized improvement over time in the 4 behaviors. Raw (unstandardized) change is included, indicating that mean (SD) fruit/vegetable intake changed from 1.2 (0.9) servings per day at baseline to 5.5 (1.0) servings per day at the end of treatment and 2.9 (2.3) servings per day at the end of follow-up. Mean (SD) minutes per day of sedentary leisure changed from 219.2 (93.8) at baseline to 89.3 (65.5) at the end of treatment and 125.7 (108.7) at the end of follow-up. Mean (SD) daily calories from saturated fat changed from 12.0% (2.2%) at baseline to 9.4% (1.9%) at the end of treatment and 9.9% (3.4%) at the end of follow-up.

Group means for each behavior in natural units (ie, minutes per day, daily servings, or percentage of daily caloric intake) are presented in **Table 2** for all treatments and are graphed in **Figure 4**.

In the increase fruits/vegetables and decrease sedentary leisure treatment group, we examined correlations among the individual behavior change estimates to determine whether changes in targeted behaviors were correlated with changes in untargeted behaviors. The degree to which participants decreased their sedentary leisure time (targeted) correlated positively with the degree to which they also reduced their fat intake (untargeted) (r<sub>52</sub> = 0.29, P = .04). Correlations among other behavior change pairs were nonsignificant and ranged from r<sub>52</sub> = -0.14 to 0.15.



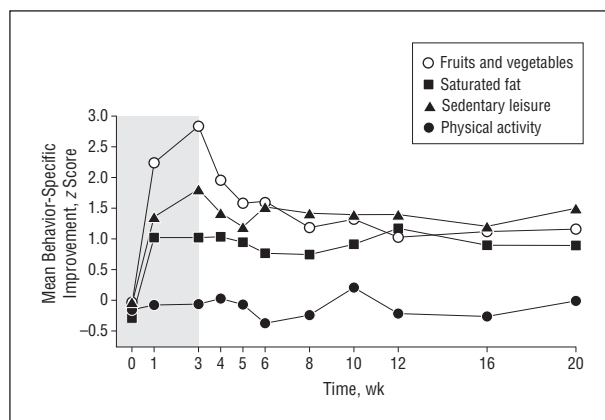


**Figure 2.** The treatments improved diet and activity to different degrees. A, Mean Composite Diet-Activity Improvement Scores over time for each of the 4 treatments. Groups differed significantly from the treatment phase throughout the follow-up phase. B, Mean Composite Diet-Activity Improvement Scores over time for fruits and vegetables and sedentary leisure treatment vs all others combined. Fruits and vegetables and sedentary leisure produced greater healthy change after 1 week; the advantage was maintained through the intervention and follow-up phases. Error bars represent SD. Gray background indicates the treatment phase (weeks 0-3); white background, follow-up without treatment (weeks 4-20); ↑, increase; ↓, decrease.

### COMMENT

This study demonstrates the feasibility of changing multiple unhealthy diet and activity behaviors simultaneously, efficiently, and with minimal face-to-face contact by using mobile technology, remote coaching, and incentives. The increase fruits/vegetables and decrease sedentary leisure treatment maximized healthy lifestyle change compared with the other interventions. In addition to producing targeted improvements in intake of fruits/vegetables and sedentary leisure time, the treatment produced untargeted improvement in saturated fat intake. The superiority of the increase fruits/vegetables and decrease sedentary leisure treatment present after 1 week of intervention persisted through the end of the 3-week treatment phase and was maintained. As expected, since participants were no longer asked to maintain healthy changes, lifestyle gains diminished once treatment ended. Nevertheless, substantial improvements (1 SD compared with baseline) in fruits/vegetables, sedentary leisure, and fat persisted through the 5-month follow-up. From baseline to the end of treatment to the end of follow-up, respectively, mean servings per day of fruits/vegetables changed from 1.2 to 5.5 to 2.9, mean minutes per day of sedentary leisure from 219.2 to 89.3 to 125.7, and daily calories from saturated fat from 12.0% to 9.4% to 9.9%. Although they were neither asked nor reinforced to maintain eating or activity improvements, 86.5% of the 185 participants from whom exit interviews were obtained said they “definitely” or “somewhat” tried to maintain gains.

Consistent with behavioral choice theory,<sup>23,24</sup> decreasing recreational screen time was complemented by a reduction in saturated fat intake. Previous research has demonstrated that manipulating screen time changes energy and fat intake in children.<sup>37</sup> This is the first study to show that reducing sedentary leisure time decreases fat intake



**Figure 3.** Mean standardized improvement in each behavior produced by the increase fruits/vegetables and decrease sedentary leisure treatment. The treatment improved both targeted behaviors (fruits/vegetables and sedentary leisure) and 1 untargeted behavior (saturated fat). Gray background indicates treatment phase (weeks 0-3); white background, follow-up without treatment (weeks 4-20).

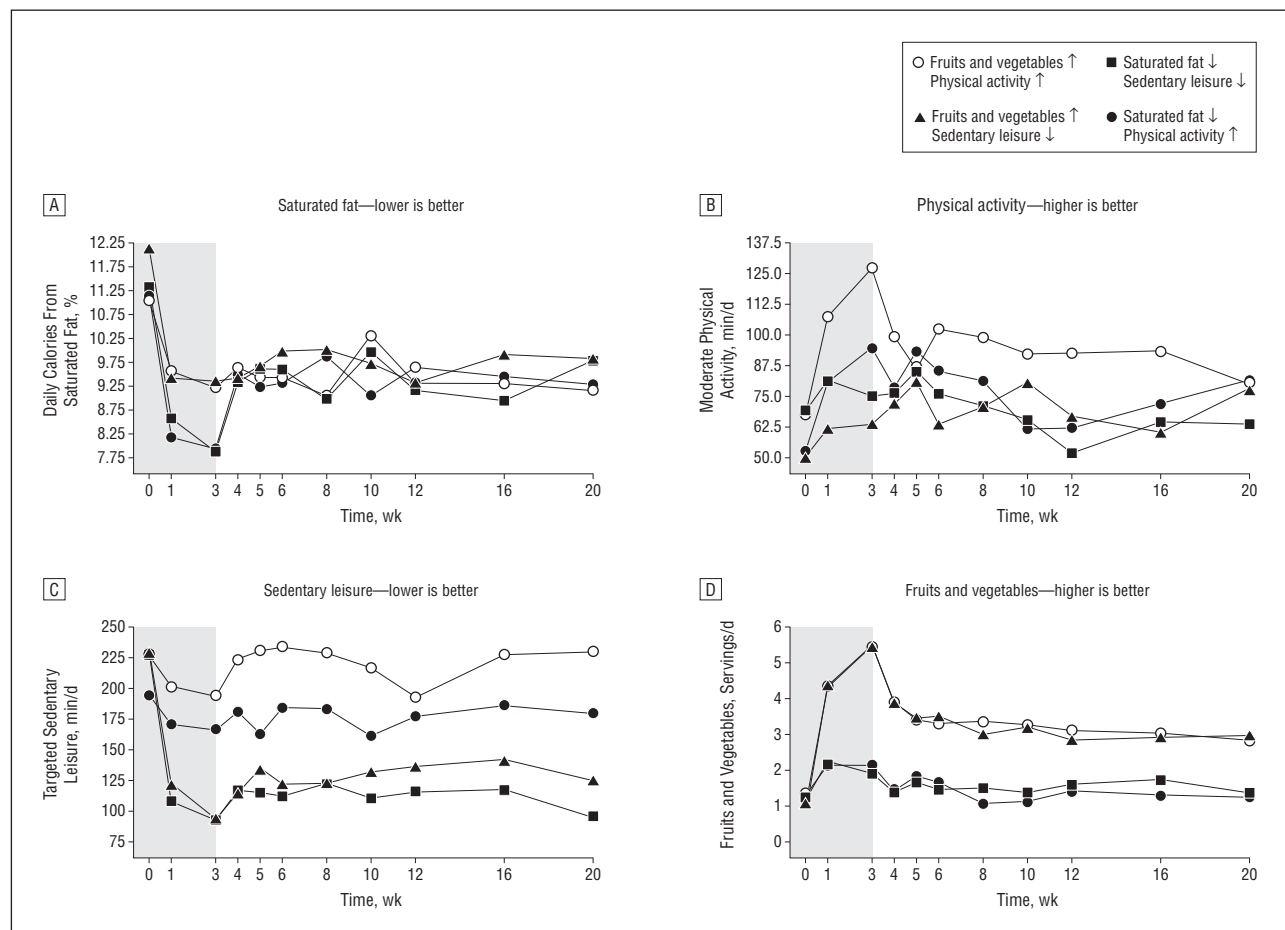
in adults. Increased interest in sedentary behavior has been driven by epidemiologic data associating sedentarism with cancer,<sup>38</sup> obesity,<sup>39,40</sup> type 2 diabetes mellitus,<sup>19,39-41</sup> depression,<sup>42</sup> cardiovascular events,<sup>19,43</sup> and increased mortality,<sup>19,43,44</sup> independent of physical activity. Reduced screen time may be an important behavioral target not only to reverse direct adverse effects of prolonged sitting<sup>45</sup> but also to disrupt pairing of screen time with high-fat snacking.

The traditional dieting regimen (decrease fat and increase physical activity) produced less healthy change than did the other treatments: it improved only 2 behaviors, and increased physical activity did not persist. The requirement to inhibit rewarding behaviors had no systematic effect on diet-activity change: the increase fruits/vegetables and physical activity treatment was no more

**Table 2. Mean (SD) Values for Each Observed Behavior in Natural Units as a Function of Treatment Group and Time<sup>a</sup>**

Characteristic	Sedentary Leisure, min	Physical Activity, min	Fruits/Vegetables, servings	Calories From Saturated Fat, %
Fruits/vegetables↑ and physical activity↑ (n = 48)				
Week 0	228.1 (100.8)	70.4 (46.8)	1.3 (1.1)	11.2 (2.0)
Week 3	206.2 (135.2)	127.1 (88.6)	5.6 (1.1)	9.3 (2.1)
Week 20	245.8 (161.8)	85.1 (73.3)	2.8 (1.9)	9.8 (3.2)
Saturated fat↓ and sedentary leisure↓ (n = 53)				
Week 0	232.1 (91.6)	66.0 (59.8)	1.4 (1.1)	11.3 (2.3)
Week 3	89.5 (75.2)	76.8 (85.7)	1.9 (1.6)	7.8 (1.8)
Week 20	103.2 (77.1)	63.7 (58.8)	1.5 (1.5)	9.6 (4.2)
Fruits/vegetables↑ and sedentary leisure↓ (n = 56)				
Week 0	219.2 (93.8)	49.6 (36.3)	1.2 (0.9)	12.0 (2.2)
Week 3	89.3 (65.5)	64.0 (78.0)	5.5 (1.0)	9.5 (1.9)
Week 20	125.7 (108.7)	74.5 (87.6)	2.9 (2.3)	9.9 (3.4)
Saturated fat↓ and physical activity↑ (n = 47)				
Week 0	199.0 (82.3)	50.7 (47.4)	1.1 (0.9)	11.4 (1.9)
Week 3	182.3 (100.4)	95.5 (65.9)	1.7 (1.1)	7.8 (1.9)
Week 20	188.3 (114.5)	78.1 (75.6)	1.3 (1.4)	9.1 (4.1)

<sup>a</sup>Week 3 is the end of treatment. Week 20 is the end of no-treatment follow-up. ↑ Indicates increase; ↓, decrease.



**Figure 4.** Effects of the 4 treatments on changes over time in each behavior expressed in natural units. Gray background indicates treatment phase (weeks 0-3); white background, follow-up without treatment (weeks 4-20); ↑, increase; ↓, decrease.

advantageous than were the other treatments, and the decrease fat and sedentary leisure treatment was no more disadvantageous.<sup>24</sup>

These results are germane to physicians trying to help patients improve multiple health risk behaviors. Physicians play an important role by advising and assisting pa-

tients to accomplish healthy behavioral changes,<sup>9,46</sup> especially since a trusting relationship with a provider is associated with greater adherence to advice.<sup>3</sup> However, limits on physicians' time combined with movement toward new systems of patient-centered, team-based care<sup>47</sup> creates an opportunity to reconsider the optimal locus and configuration of health behavior change counseling. Results suggest feasibility and potential benefit of a systems reconfiguration that reinforces health behavior change by connecting patients with mobile technology, incentives, and remote, nonphysician coaches.

Several study limitations warrant consideration. Generalizability of the findings is limited by the constraints that the study was conducted in a research setting, and only a quarter of the sample was male. Use of a screening phase to confirm the presence of the risk behaviors may additionally limit generalizability to those with entrenched unhealthy diet and activity behaviors. Also, the amount of the financial incentive was larger than would be feasible for some settings. It remains to be determined whether such rapid and full acquisition of behavior change targets would occur with smaller incentives. Furthermore, the fact that primary outcome measures were self-reported raises the possibility that participants might have overstated their behavioral improvements to earn incentives. We find that unlikely for several reasons. First, treatment differences remained after controlling for the effects of financial motivation and social desirability. Second, the sample ranked financial motives lowest among their reasons to join the trial. Third, maintaining diet and activity improvements yielded no financial reward during follow-up, an altered contingency made apparent to participants by staff reminders and by discontinuation of study procedures (urine samples, accelerometry, and grocery receipts) that could have verified self-reports. Yet, participants maintained substantial improvements, and most said they did so intentionally.

Finally, although physical activity was increased by treatments that targeted it, it was the one behavior not improved by the increase fruits/vegetables and decrease sedentary leisure treatment. We currently are testing whether all 4 risk behaviors can be improved by targeting physical activity simultaneously or sequentially with fruits/vegetables and sedentary leisure.

The strengths of the study include the ethnic diversity of the sample and minimal loss to follow-up. Also, the sample was deliberately chosen to present challenges for behavior change. The requirement that participants unremittably display all 4 risk behaviors throughout baseline screening, even while self-monitoring, yielded a sample with risk behaviors that were refractory to lower-intensity behavioral intervention. A key innovation was the use of mobile technologies that connect and provide decision support to patients and coaches, reducing the need for professionals to perform counseling. Another strength was the conservative, comparative research design that contrasts active treatments.

Interventions that target multiple, prevalent, covariant risk behaviors simultaneously have the potential to be powerfully efficient and cost-effective. Yet, many multiple behavior change interventions have achieved lim-

ited success,<sup>48-50</sup> presumably because their interventions were insufficiently intensive.<sup>51</sup> As mobile technologies become increasingly ubiquitous, they afford a scalable platform to extend continuing support for healthy behavior change pervasively into the environment, with the potential to improve population health.

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**Online-Only Material:** The eFigure and eAppendix are available at <http://www.archinternmed.com>.

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**INVITED COMMENTARY**

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## Leveraging Technology for Multiple Risk Factor Interventions

**H**ealth risk behavior change research has focused predominantly on a single risk factor, but most of the general population (58%) has 2 or more chronic disease risk factors.<sup>1</sup> Intuitively, interventions that target multiple risk factors should improve the prevention of disease better than single risk factor inter-

ventions, but systematic reviews of multiple risk factor interventions have produced disappointing results.<sup>2</sup> In this issue of the *Archives*, Spring et al<sup>3</sup> provide examples of 2 innovative research directions that have the potential to improve outcomes in multiple risk factor intervention research.