DOES EFFECTIVENESS OF WEIGHT MANAGEMENT PROGRAMS DEPEND ON THE FOOD ENVIRONMENT?

EVIDENCE FROM A NATIONWIDE PROGRAM

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ABSTRACT

OBJECTIVE

To estimate the causal effects of a population-scale behavioral weight management program and to determine whether the program's effectiveness depends on participants' geographic access to places to purchase healthy and less healthy foods.

DATA SOURCES

Secondary data from U.S. Department of Veterans Affairs clinical and administrative records (2008-2014), retail food environment measures from commercial databases (2008-2014), and the American Community Survey (2009-2014).

STUDY DESIGN

We estimated the effect of the VA's MOVE! weight management program on body mass index after 6 months using difference-in-difference regressions to compare participants with a propensity-score-matched control group. We estimated treatment effects overall and in sub-groups with different access to supermarkets, fast-food restaurants, and convenience stores.

PRINCIPAL FINDINGS

MOVE! reduced BMI by about 0.71 units among men and 0.70 units among women. The program was slightly less effective for men living near fast-food restaurants or convenience stores. We found no evidence that treatment effects varied with the food environment among women.

CONCLUSIONS

The residential food environment modestly alters MOVE! effectiveness among men. A greater understanding of environmental barriers to and facilitators of intentional weight loss is needed. This study highlights important potential intersections between healthcare and the community.

Key Words. Obesity, weight management, residential environment, retail food outlets, veterans

BACKGROUND

Despite decades of outreach and research on prevention and treatment, obesity remains a chief threat to the health of the United States (U.S.) population. Currently, about 35.2% of adult men and 40.5% of adult women are obese (Flegal et al. 2016). A recent poll found that 54% of adult Americans want to lose weight and 25% are "seriously trying to lose weight" (Swift 2016). Those numbers line up with the National Health and Nutrition Examination Survey (NHANES) (Tyrovolas et al. 2016; Yaemsiri, Slining, and Agarwal 2011), and with market research suggesting weight loss is a $59.8 billion industry (Marketdata Enterprises, 2015). Unfortunately, most people are unsuccessful in losing weight despite multiple attempts (Santos et al. 2017).

Scores of clinical trials have tried to identify effective interventions. One of the largest trials found that the Diabetes Prevention Program (DPP) produces weight loss, prevents diabetes, and reduces need for glucose-lowering medication (Knowler et al. 2002). The DPP aims to achieve a negative energy balance through calorie restriction and physical activity by helping people develop skills related to self-monitoring, stimulus control, goal-setting, and problem solving (Wing 2004). Under controlled conditions, participants in behavioral weight management interventions like the DPP lose 7%-10% of their baseline weight, which is enough to have measurable impacts on health (Knowler et al. 2002; Look AHEAD Research Group et al. 2007; Tuomilehto et al. 2001; Whelton et al. 1998). Scaled up versions of the DPP intervention are less successful, apparently because of problems with access, enrollment, adherence, and other factors (Aziz et al. 2015; Dunkley et al. 2014; Hartmann-Boyce et al. 2014; Whittemore 2011).

In real-world settings, weight management interventions may generate heterogeneous treatment effects, with many people losing clinically unimportant amounts of weight (Fitzgibbon et al. 2011; Wing et al. 2004). One hypothesis is that weight management interventions work better when people live in environments that support weight loss. Recent research suggests food environments influence body weight (Sallis and Glanz 2009). For example, some studies find that people living near supermarkets weigh less (Larson, Story, and Nelson 2009; Moore et al. 2008; Morland, Diez Roux, and Wing 2006).

The Weight and Veterans' Environments Studies (WAVES) I and II are retrospective cohort studies links between residential environments and body weight, metabolic risk, and participation in and effectiveness of a behavioral weight management program operated by the US Department of Veterans Affairs (VA) (Zenk et al. 2018). The MOVE! program is based on the DPP (Kinsinger et al. 2009; U.S. Department of Agriculture). The VA implemented the program in medical centers and clinics nationwide in 2006. Participants receive individualized treatment plans and group and individual counselling. A recent systematic review of MOVE! studies found five studies reporting mean 6-month weight change from any MOVE! participation; weight change ranged from $^{-}0.95$ kg to $^{-}1.84$ kg ($^{-}2.1$ lb to $^{-}4.1$ lb) (Maciejewski et al. 2018). These studies often rely on pre-post designs without a comparison group and examine MOVE! in a particular location.

We evaluated MOVE! using a large nationwide sample. We estimated the average effect of MOVE! across all environments in the sample. However, our main objective was to determine whether MOVE! treatment effects depend on whether patients have residential access to places to purchase healthy and less healthy foods. We hypothesized that MOVE! would induce more weight loss among participants with greater geographic access to supermarkets, which tend to provide a wider variety of healthy foods at reasonable prices than other outlets (Glanz et al. 2007; Liese et al. 2007; Sallis et al. 1986). In addition, we expected that MOVE! would be less effective among participants with greater access to fast-food restaurants or convenience stores, which tend to provide energy-dense, nutrient-poor foods and few healthy options (Glanz et al. 2007; Liese et al. 2007).

METHODS

We evaluated the effects of the MOVE! program using a retrospective longitudinal cohort study. In a first step, we constructed inverse propensity score weights to form a control group of non-participants who closely matched the participants on baseline measures of demographic, clinical, socioeconomic, and other covariates (Zenk et al. 2018). To minimize bias from unmeasured factors, we estimated treatment effects using difference-in-differences (DID) regressions. The DID regressions adjust for unmeasured confounders that escaped the matching step as long as the confounders are either time invariant or group invariant.

Patient level data came from the VA Corporate Data Warehouse and the VA/CMS data repository, which include data from clinical and administrative data including electronic health records. Retail food environment data came from InfoUSA (supermarkets, convenience stores) and Dun and Bradstreet (fast-food restaurants). Environmental covariates came from InfoUSA (commercial fitness facilities), NAVTEQ and TeleAtlas (parks), and the American Community Survey (ACS; census tract demographics).

Sample

The study sample was male and female veterans, 20-80 years old, who received primary healthcare services in the VA in 2009-2014 and lived in a continental US metropolitan area. We excluded people without at least one VA healthcare encounter in the two years prior to baseline, with long-stay nursing home residence, without at least one home address that was geocodable to the street or ZIP+4 level and to an ACS census tract, and without valid and clinically plausible height (at least one) and weight (at least two) measurements.

Matched Treatment and Control Groups

MOVE! participants were patients with at least two MOVE! visits within a 6-month period and no MOVE! visits during the 12 months before the first visit. The group of non-participants is much larger than the participant sample. And the groups have a different mix of baseline covariates. In the first stage of our analysis, we estimated each person's propensity to participate in MOVE! given baseline covariates and constructed inverse propensity score weights. We started by fitting a parsimonious logistic regression specification and used the resulting weights ($w_i = \frac{p(x_i)}{1-p(x_i)}$) to assess covariate balance according to standardized mean differences. When the standardized mean difference was more than 0.05 for a given covariate, we fit a new logit model that allowed for more flexibility using interaction terms and polynomial transformations. Ultimately we adopted a model that achieved a high level of balance on all covariates (Rosenbaum and Rubin 1984; Zenk et al 2018). The search for a propensity score model that balances the data did not involve any analysis of post-treatment outcome measures.

Measures

The outcome variable was body mass index (BMI) (weight in kg/height in m^2) calculated from height and weight measurements taken during healthcare encounters. We constructed a BMI measure for each person at baseline and at 6 months follow-up. To reduce measurement error, we set each person's height equal to his/her modal height measurement during the study period. The timing of baseline and follow up in our study is complicated because we work with data collected during health care encounters rather than study-designed contact dates. We used the first MOVE! visit as the baseline date for each MOVE! participant. And we set a target follow-up date equal to baseline date plus 180 days. To form the follow up BMI observation, we used the weight measurement collected closest in time to the target date, provided it was no more than 60 days away from the target. For the control group, baseline was the date on which the first weight measurement in a 6-month "intervention" period was taken and the follow-up weight was selected in the same manner as for MOVE! participants. Because multiple 6-month observation periods were available for many controls and to ensure that the observation periods were distributed over the 2009-2014 study period as evenly as possible, we randomly selected the observation period from all available observation periods for each control group member.

Independent variables were MOVE! participation and geographic access to supermarkets, fast-food restaurants, and convenience stores, operationalized as availability within specified distances of home. Supermarkets are viewed as sources of healthy foods, and fast-food restaurants and convenience stores as sources of unhealthy foods with few healthy alternatives (Glanz et al. 2007; Liese et al. 2007; Sallis et al. 1986). We measured availability as outlet counts within a 3-mile radius (for supermarkets and fast-food restaurants) or a 1-mile radius (for convenience stores) of each subject's home, using the home address in VA records on September 30th of their baseline year. Specifically, we divided the continental U.S. into a grid of 30m x 30m cells (approximately 8.98 billion cells), and assigned each geocoded home address to a cell. Then we counted the number of outlets of each type within the 3- or 1-mile radius of the cell's centroid. Although evidence on distances people typically travel for food based on food outlet type is somewhat limited and differs according to age, gender, income, education, urbanicity, and other area characteristics, studies have found average travel distances of 2, 3, or more miles for grocery shopping and for fast-food restaurants (Hirsch and Hillier 2013; Kerr et al. 2012; Liu, Han, and Cohen 2015; Zenk et al. 2014). Convenience stores, in contrast, are often located to attract foot traffic, particularly in highly urban areas, and studies have found shorter median distances traveled for snack food and soft drink purchases and positive associations of BMI with convenience store locations within smaller distances (D'Angelo et al. 2011; Rose et al. 2009). We constructed 4-category measures for supermarket and fast-food restaurant counts within 3 miles and for convenience stores within 1 mile. For supermarkets and convenience stores, categories were 0 stores and 3 additional levels corresponding to tertiles of the non-zero distribution. For fast-food restaurants, categories corresponded to quartiles of the full sample distribution. To check the sensitivity of our results to the measure of availability, we created two additional measures: straight-line distance from home to the nearest of each outlet type, categorized as quartiles of the distribution, and the number of supermarkets divided by the combined number of supermarkets, fast-food restaurants, and convenience stores within 3 miles ("healthy food outlet share"), which we tested as both continuous and quartiles.

We used a dichotomous measure of MOVE! exposure, equal to 1 for MOVE! participants and 0 for controls. Individual, group, and telephone MOVE! visits were ascertained using clinic stop codes, an identifier assigned by the VA Managerial Cost Accounting Office that defines the specific clinical service the patient received.

Person-level covariates included age (single-year dummy variables), race/ethnicity (non-Hispanic white, non-Hispanic black, Hispanic, non-Hispanic other, unknown), marital status (married, separated or divorced, widowed, single, unknown) and ten chronic health conditions associated with both BMI and diet and/or physical activity (breast cancer, cerebrovascular disease, colon cancer, congestive heart failure, depression, diabetes, hyperlipidemia, hypertension, myocardial infarction, and osteoporosis), the pathways through which the environment is assumed to affect BMI. Regression models also included a covariate capturing the time (in days) between the 180-day target follow-up and the actual measurement date, distance between home address and the nearest VA facilities for outpatient care and inpatient care, and facility and month-year fixed effects.

Area-level covariates included park counts (0, 1, 2-3, $\geq$4) and commercial fitness facility counts (0, 1-2, 3-4, $\geq$5) within a 1-mile radius, and census tract demographics (ACS 2009-2014 5-year estimates of population density [quartile indicators], median household income [decile indicators], and percent living below the federal poverty level [decile indicators], based on their continental US census tract distributions). Models also included census division and urbanicity (at the county level: large central metro, large fringe metro, medium metro, and small metro) (Ingram and Franco 2014) fixed effects.

Statistical analyses

We estimated the effects of MOVE! on BMI at 6 months follow-up by fitting DID regression models to the inverse propensity score weighted sample. We fit separate models for men and women because men comprise more than 90% of the sample and the age and marital status distributions of male and female VA patients differ greatly. We included interaction terms to allow MOVE! treatment effects to vary across sub-populations with different food outlet availability. We estimated models with the following form:

$$BMI_{it} = X_{it}\alpha + Food_{it}\theta + Move_i\lambda + Post_t\gamma + (Food_{it} \times MOVE_t)\beta_1 + (Food_{it} \times Post_t)\beta_2 + (Move_i \times Post_t)\beta_3 + (Move_i \times Post_t \times Food_{it})\delta + \epsilon_{it}$$

In the model, $Food_{it}$ is a vector of food outlet covariates, $Post_t$ is a binary variable set to one for follow-up observations, and $Move_i$ is a binary variable set to one if the person is a MOVE! participant. X_{it} is a vector that includes covariates. β_3 represents the DID estimate of the treatment effect in the reference group. δ is a vector of coefficients that measures the difference in the treatment effect among people who live near specific types of food outlets. To find the treatment effect in any particular food environment sub-group, we add the relevant δ to the reference group treatment effect.

The food outlet measures are correlated with each other, which may raise concerns about multi-collinearity in models that include multiple food environment measures at the same time. The main concern about multi-collinearity is that the standard error of estimated treatment effects will be large. One proposed strategy is to fit separate models that only include the food environment measures "one at a time". A problem with this approach is that each of the food outlet measures is also associated with BMI, which means that leaving the variables out of the model may produce omitted variable bias: the coefficients on the included food variable will also include some of the effects of the excluded variable.

To explore the problem we compared the coefficient estimates and standard errors in a set of "one-at-a-time" models with the coefficient estimates and standard errors from multivariate models that include all of the variables at once. We found that the standard errors were only slightly larger in the multivariate model suggesting concerns about imprecision because of multi-collinearity are not practically important in our sample. (This makes sense given that our sample consists of more than 1.9 million men and more than 150,000 women.) However, we also found that the magnitude of the coefficients were often much larger in the one-at-a-time models than in the multivariate models, suggesting that the one-at-a-time model led to more omitted variable bias from the left out food environment variables (see Appendix Table). Ultimately, we judged that the multivariate models were the preferred approach and so the estimates reported in the paper come from multivariate DID models that adjust for all three food outlet measures at the same time. All models accounted for clustering of individuals within counties at baseline using a Huber-White cluster robust variance matrix. We judged statistical significance at $p<0.05$. Analyses were conducted using Stata version 14.

RESULTS

The sample comprised 1,946,992 men and 157,402 women, including 77,359 and 11,929 MOVE! participants, respectively. Table 1 shows that the composition of the matched participant and non-participant sample is well balanced on all measured covariates, including baseline weight.

In a simple DID regression that controls for covariates but does not allow MOVE! treatment effects to vary with food outlet availability, we found that MOVE! participation reduced BMI by 0.707 BMI units ($p<0.001$) among men and 0.700 ($p<0.001$) BMI units among women (not shown). These estimates represent the overall (average) effect of the MOVE! program across patients in a wide range of food environments. Tables 2 (for men) and 3 (for women) show coefficients obtained from DID regressions that allowed the effects of MOVE! to vary across sub-populations with different food outlet availability. The coefficient on the MOVE! x Post term represents the matched DID estimate of the effect of MOVE! on BMI at six months for the reference group on the set of food environment variables. (In the count models, this is the effect of MOVE! among people who have no supermarkets and 13 or fewer fast-food restaurants within 3 miles and no convenience stores within 1 mile of home. In the distance models, it is the effect of MOVE among people who live the closest to supermarkets, convenience stores, and fast food restaurants.) The coefficients on the food outlet subgroups (which are from MOVE! x Post x Food Outlet three-way interaction terms) are matched DID estimates of the difference between the reference group effect and the effect among people living in particular food environments.

In both the count and the distance models, the reference group treatment effect estimate is similar (although not identical) to the effect obtained in a model that does not allow for treatment group heterogeneity across food environments. Among men, there is little evidence that MOVE! is substantially more or less effective among people who have different levels of access to supermarkets. The coefficients on the three-way DID interaction terms in both the left (outlet counts) and right (distance to nearest outlet) panels are statistically insignificant and substantively small in magnitude. There is some evidence that MOVE! was less effective for men living near the highest number of fast-food restaurants ($\geq$76 within 3 miles); they lost 0.095 BMI units ($p<0.042$) less than the reference group (0-13). This corresponds to a 12.7% smaller BMI reduction among those with the most compared to those with the fewest nearby fast-food restaurants. Coefficient estimates for smaller numbers of fast-food restaurants were also positive and together suggest a gradient in the relationship between fast-food restaurant availability and weight loss in MOVE!. However, the estimates of the three way interaction terms are quantitatively small and the we cannot reject the null hypothesis that they are simply equal to zero (14-39 restaurants: β 0.004, p=0.889; 40-75 restaurants β 0.061, p=0.075). The MOVE! treatment effect also did not seem to vary across sub-population living further from fast-food restaurants (0.25-0.45 miles: β -0.008, p=0.696; 0.46-0.89 miles: β -0.013, p=0.592; $\geq$0.90 miles: β -0.052, p=0.092). Male participants with the highest number of nearby convenience stores ($\geq$6 within 1 mile) lost 0.145 BMI units ($p<0.001$) or 19.5% less than those with no convenience stores. Coefficient estimates for 1-2 and 3-5 convenience stores were also positive but much smaller and not statistically significant. Results for distance to the nearest convenience store were similar; compared to men living closest (< 0.36 mile) to the nearest convenience store, those living 0.36 to 0.67 mile away lost about the same (β<0.001, p=0.984) but those living 0.68 to 1.39 miles and those living 1.40 miles or further from the nearest convenience store lost 0.074 (p=0.001) and 0.086 (p=0.006) BMI units (or 12.6% and 14.6%) less, respectively. We found no evidence that MOVE! effectiveness differed based on "healthy food share," i.e., ratio of supermarket count to all food outlet count, among men (Table 4).

Among women, MOVE!-related weight loss did not differ among participants based on number of supermarkets, fast-food restaurants, or convenience stores within the specified distance. There is some evidence that MOVE was more effective among people who lived further from a supermarket; women living 1.0 to 1.79 miles and those living 1.80 miles or further from the nearest supermarket lost 0.162 ($p=0.012$) and 0.204 ($p=0.017$) BMI units (or 34.8% and 43.9%), respectively, more than those living 0.55 miles or less from the nearest supermarket. Women living in areas where supermarkets comprise 5 to <8% of all three food outlet types combined lost 0.128 ($p=0.042$) BMI units less than those in areas with the smallest supermarket share (Table 4). But women in areas where supermarkets comprise >8% of the food outlets lost no more or less weight than the reference group. In an effort to gain precision in our estimates of the food environment subgroup effects in women, we also pooled the male and female samples and derived estimates from gender-MOVE! and gender-food outlet interaction terms. The results (not shown) were nearly identical to those obtained from the female-only sample.

DISCUSSION

MOVE! reduces BMI by about 0.7 kg/m^2 after six months for both men and women. MOVE! was slightly less effective for men living near high numbers of fast-food restaurants or convenience stores. MOVE treatment effects were slightly larger among men who lived at least 2/3 mile from the nearest convenience store. There was some evidence that MOVE! was more effective for women who lived at least 1 mile from the nearest supermarket and most effective for those whose nearest supermarket was 1.8 or more miles from home.

A small number of previous studies have examined the way food environments may moderate lifestyle intervention effects on body weight. Mendez, et al. (2016), in a secondary analysis of data from a study evaluating triggers for lapses or relapse after intentional weight loss, found no relationship between census tract density of grocery stores/supermarkets or restaurants and percent weight loss at 6 months among 127 overweight and obese adults participating in a group-delivered intervention. The study is quite different from ours. It did not include convenience stores, measured food outlet density at the census tract level rather than the person level, and relied on a small and predominantly female sample drawn from a single metropolitan area. Finally, the study did not include a comparison group. Jilcott Pitts, et al. (2017) assessed 6-month change in weight among 191 adults in a rural Pennsylvania county who participated in an intervention comprising four counseling sessions that were not focused on weight loss. They found greater weight loss among those living in a less healthy food environment, but in adjusted analyses found no associations between weight change or diet and proximity to supermarkets, farmers' markets, convenience stores, or fast-food restaurants.

Three studies evaluated change in dietary behaviors in relation to food outlets. Among 204 adults with metabolic syndrome in one county who were randomized to one of two dietary change interventions, Wedick, et al. (2015) found greater increases in dietary fiber and total fruit and vegetable intake among those living closer to a food store with a higher healthy food availability score. Gustafson, et al. (2012) found that among 156 low-income women randomized to an intervention to increase fruit and vegetable intake in North Carolina, an intervention effect was found only among those with low perceived availability of fruits and vegetables and low-fat foods and low objective supermarket density. And Feathers, et al. (2015), in a secondary analysis of data from an intervention designed to increase fruit and vegetable intake, found no statistically significant relationship between intervention adherence and density of retail produce locations near home for the 53 out of 70 women enrolled in the intervention for whom data were available. A key limitation in the literature is that existing research is based on relatively small sample sizes that may lack the statistical power to reliably measure treatment effect heterogeneity. Our study examines almost 2 million people living in a diverse range of residential food environments, and we controlled bias using inverse propensity score weights and DID estimation.

Our study has several limitations. We lack information on the actual behavior of the individuals in our sample. We do not know whether people living close to convenience stores shopped at those stores. Likewise, geographic proximity is not the sole determinant of someone's access to food resources. Measurement of affordability and travel time were beyond the scope of the study. We were not able to control for individual measures of socioeconomic status and so we cannot distinguish effects of individual and environmental poverty. Finally, the VA population is different from the U.S. population as a whole. In particular, the VA population has more African American and lower income persons, groups who have had poorer access to behavioral weight management programs and may benefit less from them (Butryn et al. 2017; Fitzgibbon et al. 2011; West et al. 2008). So we do not know whether the effects of a weight management program in specific food environments observed in the VA population are comparable to those in the general population. However, a recent analysis by Wong, et al. (2016) suggests that results from some studies among VA populations may be reasonably generalized to some non-VA populations.

Causal inferences in our study rest on the assumption that after matching on baseline covariates, our treatment and control groups would have experienced similar weight trajectories in the absence of the MOVE! program. The main remaining threat to internal validity in our study is a time-varying unobserved factor that is associated with MOVE! participation and affects BMI. Perhaps the most plausible example is a person level increase in motivation that led people to enroll in the program. In that case, people might have lost weight because of greater motivation rather than the program itself. Although we cannot rule out such threats, they seem unlikely to have played an important role in explaining our results. First, differences in weight-loss motivation or intent to lose weight between the treatment and control groups are likely small. Both groups demonstrate a degree of health-related motivation by virtue of having made and kept an appointment to see their VA provider. Second, some patients who decline participation in MOVE! likely do so not because they lack motivation but because they elect to enroll in a weight management program outside VA, which would have biased our overall estimates towards the null. Third, the role of motivation in determining success in achieving intentional weight loss is not established in previous research, and measured intent to lose weight is itself a poor predictor of weight loss. Finally, part of the goal of behavioral weight management programs is to help motivate and encourage people so that sustained motivational differences might simply be part of the effect of the program. In summary, modest differences in unobserved factors related to weight loss intent that may influence weight loss, together with likely weight loss in the control group resulting from unmeasured weight management program participation outside VA, lead us to believe that any potential bias upward in MOVE! effects resulting from unmeasured time-varying characteristics is likely small and without substantive impacts on our results.

Notable strengths of the study include its large sample size, allowing simultaneous examination of multiple environment attributes and complex interactions, and including large numbers of men who have historically been underrepresented in weight management studies; the ability to observe weight management program participants in diverse environments nationwide; and detailed clinical data, allowing us to control for the potentially confounding influences of chronic conditions and healthcare utilization.

While our models yielded substantively different results for men and women, we caution against drawing any conclusions about sex differences in associations of BMI change with the food environment. Direct comparisons are ill-advised because men and women in the VA population have very different age, race/ethnicity, marital status, geographic location, residential area socioeconomic, health, and military experience profiles.

Our results suggest potential new avenues for improving weight management program outcomes. Novel approaches that take into account participants' residential area contexts, including an understanding of the mix of retail food outlets may be useful. Program behavioral components could tailor self-management training to specific contexts, including that related to impulse buying in convenience stores, for example. Whether such tailoring approaches will make measurable advances in helping people lose weight is a question for future investigation.

Notwithstanding this study's findings, overall our evidence of food environment effects on weight management program outcomes is limited. Many questions remain, including about whether elements of the food environment not measured in this study (e.g., the presence of supercenters such as Costco or Walmart, food pricing and marketing) or a different definition of the local food environment (e.g., that proximate to work rather than home) may influence behaviors among men and women engaged in a weight management program and moderate outcomes. Given the high prevalence of obesity in the U.S. population, its large impacts on health and function over the life course, and the very limited benefit that most people derive from participation in weight management programs, gaining a greater understanding of barriers to and facilitators of intentional weight loss is an important public health and healthcare goal. This study highlights important intersections between healthcare and the community. Collaborations between health systems, public health entities, and communities could address those and other questions and identify efficacious population-level interventions to facilitate peoples' achievement of their weight loss goals.

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TABLE 1 SAMPLE CHARACTERISTICS: MOVE! Participants and Inverse-propensity score weighted Controls

Variable	Value	Men		Women	
		MOVE! Participants (n=77,359)	Controls (N=1,869,633)	MOVE! Participants (N=11,929)	Controls (N=145,473)
Age, mean (SD)		60.1 (9.8)	60.1 (2.1)	50.1 (10.8)	50.1 (3.3)
Race, %	Non-Hispanic White	62.6	63.6	48.6	50.4
	Non-Hispanic Black	24.8	24.0	38.6	37.4
	Non-Hispanic Other	2.1	2.1	3.0	3.0
	Hispanic	5.7	5.5	4.9	4.6
	Unknown	4.8	4.8	5.0	4.7
Marital status, %	Married	54.3	54.5	30.4	30.9
	Not married	45.2	45.0	68.9	68.4
	Unknown	0.5	0.5	0.7	0.7
Health conditions, %	Breast cancer	0.1	0.1	2.6	2.6
	Colon cancer	0.9	0.9	0.3	0.4
	CVD	6.4	6.5	3.3	3.2
	CHF	8.7	8.9	2.1	2.1
	Depression	37.4	38.0	54.4	55.0
	Diabetes	46.4	46.6	21.9	22.0
	Hyperlipidemia	65.0	65.4	41.6	42.5
	Hypertension	74.7	74.9	46.4	46.0
	MI	4.0	4.1	0.8	0.8
	Osteoarthritis	23.1	22.4	20.6	19.9
Census tract % below poverty, mean (SD)		15.6 (12.1)	15.7 (2.5)	16.3 (11.8)	16.3 (3.5)
Census tract median household income, mean $ (SD)		52,732 (21,854)	52,461 (4,566)	51,261 (20,312)	51,105 (6,034)
Census tract population density, mean (SD)		4.8 (10.0)	4.6 (2.1)	4.5 (8.6)	4.3 (2.5)
VA outpatient facility (nearest in miles), mean (SD)		27.1 (32.2)	28.8 (6.8)	25.3 (30.6)	27.6 (9.5)

VA inpatient facility (nearest in miles), mean (SD)		8.2 (7.3)	8.4 (1.6)	8.1 (6.9)	8.2 (2.1)
Urbancity, %	Large central metro	33.2	31.7	33.1	31.7
	Large fringe metro	22.7	22.4	21.7	21.2
	Medium metro	29.5	29.3	31.8	31.8
	Small metro	14.6	16.6	13.5	15.3
Census division, %	New England	4.5	4.2	2.6	2.5
	Middle Atlantic	10.3	10.1	7.7	7.3
	East North Central	17.8	17.9	14.1	14.3
	West North Central	6.1	6.3	6.0	5.8
	South Atlantic	21.5	22.2	26.8	27.5
	East South Central	5.0	4.9	6.7	6.6
	West South Central	12.4	12.1	15.2	15.5
	Mountain	10.6	10.6	10.3	10.2
	Pacific	11.7	11.7	10.7	10.4
Supermarkets (count within 3 miles), %	0	11.6	12.7	10.1	10.7
	1 - 3	25.3	25.7	25.9	26.4
	4 - 8	31.2	31.1	33.7	34.0
	9+	31.9	30.6	30.3	29.0
Supermarkets (nearest in miles), %	< 0.55	27.8	25.1	27.1	25.7
	0.55-0.99	27.5	26.3	28.7	26.8
	1.00-1.79	22.7	22.9	24.2	24.4
	$\geq$ 1.80	22.0	25.7	20.0	23.1
Fast-food restaurants (count within 3 miles), %	0 - 13	18.5	19.6	16.9	18.0
	14 - 39	25.1	25.0	26.4	25.9
	40 - 75	27.1	27.0	28.4	28.3
	76+	29.3	28.4	28.3	27.8

Fast-food restaurants (nearest in miles), %	< 0.25	28.8	26.1	27.9	26.7
	0.25-0.45	25.7	24.3	27.0	25.5
	0.46-0.89	24.6	24.6	25.3	25.5
	≥ 0.90	20.9	25.0	19.8	22.3
Convenience stores (count within 1 mile), %	0	21.3	22.2	18.6	19.4
	1 - 2	22.4	22.6	23.2	23.3
	3 - 5	25.3	25.2	27.5	27.5
	6+	31.0	30.0	30.7	29.8
Convenience stores (nearest in miles), %	< 0.36	27.7	25.0	28.0	25.8
	0.36-0.67	26.3	25.0	27.7	26.2
	0.68-1.39	25.0	25.3	25.5	26.7
	≥ 1.40	21.0	24.7	18.8	21.3
Healthy food store share, mean (SD)		0.08 (0.06)	0.08 (0.06)	0.08 (0.05)	0.08 (0.06)
Parks (count within 1 mile), %	0	29.0	30.2	30.8	31.5
	1	17.6	17.7	17.8	18.7
	2 - 3	24.6	24.2	25.1	23.9
	4+	28.9	28.0	26.3	25.9
Fitness facilities (count within 1 mile), %	0	25.8	26.8	25.8	26.5
	1 - 2	28.1	28.1	29.6	29.6
	3 - 4	18.2	17.8	18.6	18.1
	5+	27.9	27.3	26.0	25.8

TABLE 2 Estimates of the Influence of Food Outlet Availability Near Home on MOVE! Effectiveness Among Men[*] (N=1,946,992)

		Counts			Distance to Nearest			
		b	p-value	CI		b	p-value	CI
MOVE! x POST[†]		-0.745	<0.001	-0.790, -0.700	**MOVE! x POST**[†]	-0.584	<0.001	-0.663, -0.505
Subgroup Effects[‡]								
Supermarkets	**0**	Ref	--	--	**< 0.55**	Ref	--	--
	1-3	0.051	0.106	-0.011, 0.113	**0.55-0.99**	-0.018	0.378	-0.058, 0.022
	4-8	0.021	0.615	-0.060, 0.101	**1.00-1.79**	-0.022	0.353	-0.069, 0.025
	9+	0.030	0.612	-0.086, 0.147	**≥ 1.80**	-0.013	0.686	-0.076, 0.050
Fast-food Restaurants	**0-13**	Ref	--	--	**< 0.25**	Ref	--	--
	14-39	0.004	0.889	-0.520, 0.060	**0.25-0.45**	-0.008	0.696	-0.049, 0.033
	40-75	0.061	0.075	-0.006, 0.128	**0.46-0.89**	-0.013	0.592	-0.059, 0.034
	76+	0.095	0.042	0.003, 0.186	**≥ 0.90**	-0.052	0.092	-0.113, 0.008
Convenience Stores	**0**	Ref	--	--	**< 0.36**	Ref	--	--
	1-2	0.020	0.437	-0.030, 0.069	**0.36-0.67**	0.000	0.984	-0.039, 0.039
	3-5	0.034	0.223	-0.021, 0.089	**0.68-1.39**	-0.074	0.001	-0.118, -0.030
	6+	0.145	<0.000	0.085, 0.205	**≥ 1.40**	-0.086	0.006	-0.147, -0.024

[*] Matched difference-in-differences (DID) estimates for supermarket and fast-food restaurants within 3 miles and convenience stores within 1 mile of home (left panel) and nearest supermarket, fast-food restaurant, and convenience store (right panel) obtained from OLS regression models controlling for age; race/ethnicity; marital status; 10 chronic health conditions; census tract median household income, percent living below the poverty level, and population density; VA facility; number of inpatient stays and outpatient provider encounters; and census division.

[†] DID estimate of the effect of MOVE! participation for the reference group.

[‡] DID estimate of the difference between the reference group effect and the effect among those living in particular food environments. Distance to nearest outlet measured in miles.

TABLE 3 Estimates of the Influence of Food Outlet Availability Near Home on MOVE! Effectiveness Among Women* (N=157,402)

		Counts			Distance to Nearest			
		b	p-value	CI		b	p-value	CI
MOVE! x POST†		-0.764	<0.001	-0.896, -0.633	**MOVE! x POST†**	-0.465	<0.001	-0.642, -0.289
Subgroup Effects‡								
Supermarkets	**0**	Ref	--	--	**< 0.55**	Ref	--	--
	1-3	0.122	0.179	-0.056, 0.301	**0.55-0.99**	-0.109	0.067	-0.225, 0.008
	4-8	0.052	0.661	-0.178, 0.281	**1.00-1.79**	-0.162	0.012	-0.288, -0.036
	9+	0.035	0.806	-0.241, 0.310	**≥ 1.80**	-0.204	0.017	-0.371, -0.037
Fast-food Restaurants	**0-13**	Ref	--	--	**< 0.25**	Ref	--	--
	14-39	-0.024	0.740	-0.167, 0.118	**0.25-0.45**	-0.029	0.637	-0.151, 0.093
	40-75	0.079	0.394	-0.103, 0.262	**0.46-0.89**	-0.023	0.717	-0.144, 0.099
	76+	0.162	0.139	-0.053, 0.377	**≥ 0.90**	0.008	0.923	-0.153, 0.169
Convenience Stores	**0**	Ref	--	--	**< 0.36**	Ref	--	--
	1-2	-0.017	0.798	-0.149, 0.115	**0.36-0.67**	-0.015	0.804	-0.130, 0.101
	3-5	0.079	0.242	-0.053, 0.211	**0.68-1.39**	-0.025	0.702	-0.151, 0.102
	6+	0.030	0.695	-0.119, 0.178	**≥ 1.40**	-0.085	0.298	-0.246, 0.075

* Matched difference-in-differences (DID) estimates for supermarket and fast-food restaurants within 3 miles and convenience stores within 1 mile of home (left panel) and nearest supermarket, fast-food restaurant, and convenience store (right panel) obtained from OLS regression models controlling for age; race/ethnicity; marital status; 10 chronic health conditions; census tract median household income, percent living below the poverty level, and population density; VA facility; number of inpatient stays and outpatient provider encounters; and census division.

† DID estimate of the effect of MOVE! participation for the reference group.

‡ DID estimate of the difference between the reference group effect and the effect among those living in particular food environments. Distance to nearest outlet measured in miles.

TABLE 4 Estimates of the Influence of Healthy Food Outlet Share on Move! Effectiveness*			
MEN			
	b	**p-value**	**CI**
MOVE! x POST†	-0.689	<0.001	-0.737, -0.642
Subgroup Effects‡			
Healthy food outlet share			
0 - <0.05	Ref	--	--
0.05 - <0.08	-0.016	0.537	-0.067, 0.035
0.08 - <0.11	-0.037	0.217	-0.095, 0.022
>=0.11	-0.016	0.659	-0.085, 0.054
WOMEN			
	b	**p-value**	**CI**
MOVE! x POST†	-0.718	<0.001	-0.828, -0.607
Subgroup Effects‡			
Healthy food outlet share			
0 - <0.05	Ref	--	--
0.05 - <0.08	0.128	0.042	0.004, 0.252
0.08 - <0.11	0.073	0.264	-0.055, 0.201
>=0.11	-0.036	0.542	-0.154, 0.081

* Healthy food outlet share was calculated as the number of supermarkets divided by the sum of the number of supermarkets, fast-food restaurants, and convenience stores within 3 miles. Matched difference-in-differences (DID) estimates obtained from OLS regression models controlling for age; race/ethnicity; marital status; 10 chronic health conditions; census tract median household income, percent living below the poverty level, and population density; VA facility; number of inpatient stays and outpatient provider encounters; and census division.
† DID estimate of the effect of MOVE! participation for the reference group.
‡ DID estimate of the difference between the reference group effect and the effect among those living in particular food environments.