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The PHLAME (Promoting Healthy Lifestyles: Alternative Models' Effects) Firefighter Study: Testing Mediating Mechanisms

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Abstract

This paper examines the mechanisms by which PHLAME (Promoting Healthy Lifestyles: Alternative Models' Effects), a health promotion intervention, improved healthy eating and exercise behavior among firefighters, a population at high risk for health problems due to occupational hazards. In a randomized trial, 397 firefighters participated in either the PHLAME team intervention with their work shift or a control condition. Intervention sessions taught benefits of a healthy diet and regular exercise and sought to improve social norms and social support from coworkers for healthy behavior. At post-test team intervention participants had increased their fruit and vegetable consumption as compared to control participants. An increase in knowledge of fruit and vegetable benefits and improved dietary coworker norms partially mediated these effects. Exercise habits and VO2 max were related to targeted mediators but were not significantly changed by the team intervention. Partial support was found for both the action and conceptual theories underlying the intervention. Our findings illustrate how an effective program's process can be deconstructed to understand the underpinnings of behavior change and refine interventions. Further, fire stations may improve the health of firefighters by emphasizing the benefits of healthy diet and exercise behaviors while also encouraging behavior change by coworkers as a whole.

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Keywords

health promotion intervention; work team

An estimated 380,000 premature deaths each year in the U.S. may be prevented through increased physical activity and improved nutrition (Mokdad, Marks, Stroup, & Gergerding, 2005). Despite the benefits of recommended diet and exercise behaviors, however, most Americans do not exercise regularly or consume a balanced diet (Reeves, & Rafferty, 2005). Regular exercise and healthy eating habits have been shown to share common features and there is evidence that the two behaviors act synergistically to promote health (Blair, et al., 1996). Therefore, interventions to promote both exercise and healthy eating have the potential to greatly improve health.

Despite public perceptions that firefighters are fit, their health profile is comparable to other workers, with many engaging in the most prevalent harmful behaviors including an unhealthy diet and a lack of regular physical activity leading to obesity and other related health issues (Horowitz, & Montgomery, 1993). Firefighters are at a heightened risk for cancer (LeMasters, et al., 2006; Kang, Davis, Hunt, & Kriebel, 2008), heart disease (Byczek, Walton, Conrad, Reichelt, & Samo, 2004) and musculoskeletal injuries (Moore-Merrell, Zhou, McDonald-Valentine, Goldstein, & Slocum, 2008) due to job-specific occupational hazards. Heart disease was the most frequent cause of death among on-duty firefighters between 1994 and 2004, and accounted for 45% of deaths fighting fires (Kales, Soteriades, Chrisophi, & Christiani, 2007). Kales, et al (2007) suggested that the risk of cardiac events during fire suppression, a time when firefighters are engaged in intense physical activity, was increased due to a lack of adequate physical fitness as well as underlying cardiovascular risk factors. Moore-Merrell et al (2008), through a review of 3450 injury cases within nine geographically diverse metropolitan fire departments in the U.S., concluded that 28.57% of injuries were the result of a lack of wellness/fitness.

Despite the fact that firefighters' lack of optimal fitness puts them at increased risk for negative health outcomes, the majority of fire departments do not have programs to promote fitness and health (Fahy, 2005). As with interventions with the general population, attempts to change diet and exercise behaviors among firefighters have not always been successful and more research is needed to understand how to best intervene (Green, & Crouse, 1991). Worksites have been identified as potentially promising arenas for health promotion. Interventions within these natural settings may take advantage of environmental restructuring and altering of social norms to benefit both workers and employers (Pelletier, 2005).

The PHLAME (Promoting Healthy Lifestyles: Alternative Models' Effects) intervention was developed to promote healthy eating and physical fitness among firefighters and was designed to be implemented within fire stations. This theory-based worksite health promotion intervention was originally funded by the National Institutes of Health as a member of the Behavior Change Consortium as one of several projects designed to assess new models of behavior change for healthy dietary habits and physical activity (Ory, Jordan, & Bazzarre, 2002). The PHLAME project involved the implementation and evaluation of two health promotion formats. The first was a team-centered peer taught curriculum. The second involved one-on-one motivational interviewing. Funding for the project was continued by the National Cancer Institute and the Office of Behavioral and Social Sciences Research as a member of the Health Maintenance Consortium (Health Maintenance Consortium Resource Center, 2009) to study behavior maintenance.

The purpose of the current study is to understand, through mediation analyses, how the PHLAME team-centered intervention affected health behaviors. Prior reports have described interventions rationale and activities (Moe, et al., 2002) and the beneficial effects of PHLAME on fruit and vegetable consumption, general well being, and body mass index (Elliot, et al., 2007). Recently, MacKinnon et al (2010) reported on the long term effects of both PHLAME interventions. These results from seven waves of data showed positive program effects on dietary support, knowledge of fruit and vegetable benefits, daily servings of fruits and vegetables and body mass index. The strongest effects of the program were observed at the second wave of data and for the team intervention. These effects were the focus of the mediation analyses. Analyses were limited to the first two waves of data collection because the intervention occurred between these two time points and both the mediators and outcomes were hypothesized to change prior to the second wave of data collection. In this way, analyses best test the action theory. In addition, by including post-test mediators and post-test outcomes, we provide the strongest test of the conceptual theory.

The mediation analyses were informed by the underlying theoretical model of the intervention. The two intervention formats assessed in the PHLAME study were each based on different theoretical models (Moe, et al., 2002). The theory underlying the team intervention was developed using Social-Cognitive Theory (Bandura, 1986; Perry, Baranowski, & Parcel, 1990) and the Health Belief Model (Rosenstock, 1974; Janz, Champion, & Strecher, 2002) and informed the program content of the multiple group-based sessions. The one-on-one motivational interviewing intervention was theoretically grounded in intrinsic motivation and self-determination theory (Ryan & Deci, 2000; Miller & Rollnick, 2002; Miller & Rose, 2009) and was individualized according to the participant. Because of the different underlying theories, the current paper presents the mediation analyses for only the team intervention.

The purpose of the mediation analyses in the current study was to: (1) investigate the extent to which the program changed the mediators targeted by the PHLAME team-centered curriculum, (2) investigate the extent to which the mediators targeted were related to outcomes of interest, and (3) test the process by which the PHLAME program had its effects on the behavioral outcome variables. In addition to evaluating whether the program improved outcomes, it is important to understand the process by which the program achieved effects (Baranowski, Anderson, & Carmack, 1998; Kristal, Glanz, Tilley, & Li, 2000). Within an intervention, multiple constructs or hypothesized mediators may be targeted in an effort to impact a specific outcome. Mediation analyses can determine the extent to which the intervention affected the outcome through each hypothesized mediator. In this way, analyses help define the contribution of different program components as well as provide a check on the intervention's theory. Important for intervention development and revision, mediation analysis informs researchers' decisions concerning improvements, modifications, and cost-effectiveness of program components. Several recent reviews have noted the increasing number of articles which involve mediation analyses for the understanding of interventions (Lockwood, DeFrancesco, Elliot, Beresford, & Toobert, 2010; MacKinnon & Fairchild, 2009; Fairchild & McQuillin, 2010).

When using mediation analyses to evaluate an intervention, two parts of the program should be considered (MacKinnon, 2008). These two parts are the action theory (specifies which aspects of the program are designed to target hypothesized mediators) and the conceptual theory (specifies which targeted mediators are hypothesized to relate to specific outcomes). Figure 1 shows a single mediator model. In the top portion of the figure, the *c* path, or total effect of the intervention on an outcome is depicted. Explaining the process by which this total effect was achieved is the purpose of subsequent mediation analyses. In the bottom portion of Figure 1, the relations among 3 variables, the intervention, an outcome, and a

mediator are represented. The action theory is represented by the a path and the conceptual theory is represented by the b path. The c' path, or direct effect, depicted in Figure 1 represents the effect of the intervention on the outcome that is not mediated through the one or more hypothesized mediators in the model.

Through mediation analyses, researchers can test the hypothesized process by which change occurred through the examination of both the action theory and the conceptual theory. Investigation of action and conceptual theory is important for outcomes without statistically significant program effects because they can be used to help understand why statistically significant effects were not obtained. Although Figure 1 shows only one mediating variable, most health promotion programs, such as the PHLAME program, target behavior change through multiple mediating variables. Mediation analyses allow a better understanding of the effects of an intervention and aid in determining whether an intervention achieved its targeted programmatic goals, and whether those targeted objectives ultimately related to the intervention's outcomes (MacKinnon & Dwyer, 1993).

The PHLAME Program and its Action and Conceptual Theories

Firefighters at stations assigned to the PHLAME team intervention condition participated in 11, 45-minute sessions over the course of a year with their shift. One member of each shift or team became the designated team leader. That individual used an easy to follow manual with explicitly scripted lesson plans, while other team members used corresponding workbooks. Team members participated in activities concerning nutrition, exercise, energy balance, and other topics selected by the team members themselves. Each session was designed in accordance with the action theory to include activities that targeted one or more hypothesized mediators. The intervention was designed to have an interactive learning format which allowed for personalizing the discussion. Firefighters decided when they would hold the sessions and chose what extra content, aside from the core material, that they covered. These features, along with completing the program with their close team members, likely contributed to some feelings of program ownership. More details of the PHLAME program are available at <http://rtips.cancer.gov/rtips/programDetails.do?programId=288026>.

As depicted in Table 1, specific program activities in specified sessions were included to target each mediator, illustrating the action theory of the PHLAME team-centered intervention. Activities used principles of adult learning and were designed to be interactive and enjoyable and emphasize relevance, active learning and application of new abilities (Knowles, Holton, & Swanson, 2005). Participating in the program with their co-workers as a team was designed to change dietary norms among the group and encourage exercising together. As an occupation, firefighting is uniquely suitable for a team-centered intervention. In general, firefighters work at a specific fire station, where they are members of one of three shifts. Each shift works 24 hours, followed by 48 hours off. Shift members work as a unit or team. During their shift, firefighters live at the station, which has facilities for dining and sleeping. Firefighter shift members naturally form a team. Teams are unique from other kinds of groups in that teams have interdependence among members, complementary abilities, a common commitment, mutual accountability, and an identity that results in a team's effects being greater than the sum of its members (Katzenbach & Smith, 2005). In this way, teams have the potential to influence their members by heightening interpersonal influence and support. All of the hypothesized mediators that were included in the current analyses were targeted in multiple intervention sessions. Table 1 makes explicit which sessions of the PHLAME program targeted each mediator.

Relationships among constructs that are tested in the PHLAME intervention appear within established models of health behavior including Social-Cognitive Theory (SCT; Bandura,

1986; Perry, Baranowski, & Parcel, 1990) and the Health Belief Model (HBM; Rosenstock, 1974; Janz, Champion, & Strecher, 2002). SCT describes behavior as the result of observational learning, social norms, imitation and modeling. Modeling of behaviors by others can establish new behaviors and increase the frequency of previously learned behaviors. A major component of the PHLAME intervention was completing sessions with peers. As supported by SCT, learning about healthy behaviors with others was believed to change social norms among work teams and encourage firefighters to learn by observing others and modeling their peers as they adopted more healthy behaviors. Further, SCT discusses the importance of self-regulation which involves setting goals, monitoring behaviors and self-reinforcement. PHLAME participants were encouraged to set dietary goals and keep track of their dietary intake which was believed to increase their fruit and vegetable intake and decrease their fat intake. The link between behavior and three of the mediators tested, social norms for dietary behavior, social support for exercising and monitoring dietary intake, are supported by SCT.

The HBM describes health behavior as a result of four beliefs: a person's perceived benefits of a preventive behavior, their perceived susceptibility to a negative outcome, their perceived severity of that outcome, and their perceived barriers toward that behavior. Teaching about the benefits of fruit, vegetables, and exercise was a major component of the intervention. The HBM supports a hypothesized relationship between increases in knowledge of benefits and behavior. Table 2 depicts the conceptual theory of the PHLAME team-based intervention and makes explicit which relationships are expected based on SCT and HBM.

Using these two main theories, multiple mediators of behavior change were targeted. Specific mediators included knowledge of the benefits of fruit and vegetables intake and of exercise, personally monitoring dietary intake, dietary coworker norms, and coworker social support for exercise. Thus, in program sessions, participants were taught about benefits of eating fruits and vegetables and benefits of exercise. Participants were read information and also interacted with each other through discussion and games which helped them retain the information.

In a recent meta-analysis of papers describing psychosocial predictors of fruit and vegetable intake, strong evidence was found in support of relationships between knowledge of benefits and social support with fruit and vegetable intake (Shaikh, Yaroch, Nebeling, Yeh, & Resnicow, 2008). In addition to being taught about proper nutrition for firefighters, participants learned how to monitor what foods they consume daily. They were given tables on which to record their dietary intake. In an intervention targeting changes in diet and body weight through self-monitoring of food intake, each additional day that participants self-monitored their diet resulted in a decrease in body mass index (Miller, Gutschall, & Holloman, 2009). Personal monitoring of diet has also been shown to increase vegetable and whole grain consumption (Atienza, King, Oliveira, Ahn, & Gardner, 2008). As previously mentioned, firefighters participated in the program with their coworkers. Many of the program activities were interactive and involved discussion. The improved social norms and increased social support hypothesized to be associated with this design was believed to increase corresponding healthy behaviors.

Method

Participants

Analyses included 397 firefighters who participated in either the team or control condition of the study. Firefighters were primarily male (93%), and Caucasian (91%). The majority

had an income above \$50,000 (88%) and 28% were college graduates. Participants had a mean age of 41 years at the start of the study.

Design

Five fire departments in the Pacific Northwest were recruited for the PHLAME intervention trial. In total, 599 firefighters from 48 stations met criteria for participation. Stations underwent balanced randomization to the team-centered intervention (15 stations, 234 firefighters), motivational interviewing (16 stations, 202 firefighters), or control (17 stations, 163 firefighters) condition. The structure of the worksites allowed for randomization with minimal contamination across conditions. See Figure 2 for a CONSORT diagram of participation. As discussed, the current analyses focused on the 397 firefighters in the team and control conditions.

Measures

Firefighters were assessed by self report questionnaires, dietary instruments and physiological testing before beginning the program (pre-test) and a year later, after completing the program (1 year post-test). The measures used in the study are shown in Table 3 along with the response range for individual items and coefficient alpha reliability for measures computed as a mean of at least three items. There were four outcome variables: fruit consumption, vegetable consumption, self-reported exercise, and VO2 max. One of the four outcomes, self-reported exercise, was computed as a mean of multiple items that assessed weekly exercise over the past month. Fruit and vegetable consumption was measured as the number of servings of fruits and vegetables consumed in the past month using a validated screening instrument (Thompson, et al., 2002; Peterson, et al., 2008). Scores represent the average number of daily servings consumed over the past month. Finally, VO2 max was scored through a treadmill test by trained medical personnel. VO2 max is a measure of the maximum capacity of an individual's body to transport and utilize oxygen during incremental exercise which reflects the physical fitness of the individual.

There were five hypothesized mediating variables: knowledge of fruit and vegetable benefits, knowledge of exercise benefits, personally monitoring diet, dietary coworker norms, and exercise support. These five mediators were chosen for the current analyses because they were targeted in multiple intervention sessions, their relations to the outcomes of interest have theoretical justification, and they were reliably measured. Knowledge of fruit and vegetable benefits was calculated as a mean of six items that asked the extent to which participants agreed that eating five or more servings of fruits and vegetables per day lowers their risk for six negative health outcomes. Knowledge of exercise benefits was calculated as a mean of six items that asked the extent to which participants agreed that getting regular physical activity would improve their health. The fruit and vegetable and the exercise items asked about the following six outcomes: cancer, cardiovascular disease, diabetes, fatigue, high blood pressure, and high total cholesterol). Personally monitoring diet was assessed with one item which asked the extent to which participants kept track of their dietary intake. The dietary coworker construct was labeled "norms" because the questions asked about coworkers' dietary behaviors (i.e., How much do you agree or disagree with the following statement? My coworkers eat a low-fat diet.). Dietary coworker norms were computed as a mean of four items which asked about the fruit, vegetable, and fat intake behaviors of the participant's coworkers. The exercise coworker construct was labeled "support" because items asked about how often coworkers offer to exercise with the participant and offer encouragement for the participant's exercise (i.e., How much do you agree or disagree with the following statement? During a typical week, my coworkers exercise with me). Coworker exercise support was calculated as a mean of four items which

asked about the extent to which coworkers exercise with the participant and encourage the participant to exercise.

Mediation Models and Statistical Analyses

Each of the hypothesized mediated effects was tested within single mediator models initially and then a full model (Figure 3) was tested in which all post-test mediators and post-test outcomes were included. Relations between constructs were nearly identical when tested within single mediator models and within the full model. Further, the full model allowed for a test of individual mediated effects while holding constant the effects of other mediators. Therefore, only the results from the full model are reported. The mediational pathways specified followed the logic of the PHLAME intervention design.

Individual level models were estimated in Mplus 5.2 (Muthén & Muthén, 2008). The hierarchical clustering of participants within stations was controlled to yield accurate tests of inference (Raudenbush & Bryk, 2002). Full information maximum likelihood was employed to include all available data. Analyses controlled for pre-test differences between the team and control conditions by including pre-test measures as predictors of corresponding post-test measures. The statistical significance of mediated effects was further probed with asymmetric 95% confidence limits for the distribution of two normally distributed variables, computed by the PRODCLIN program (MacKinnon, Fritz, Williams, & Lockwood, 2007).

The focus of analyses was to examine the mediated effects of the PHLAME program on four outcomes of interest. PHLAME program assignment was represented by a dummy code variable (team intervention = 1, control = 0). Pre-test measures of the outcomes were included as predictors of the corresponding post-test outcomes, yielding a two-wave ANCOVA design for all models. Specifically, post-test outcomes were predicted by the pre-test outcome measure, relevant post-test mediators, and the intervention dummy code variable. Post-test mediating variables were predicted by the pre-test mediating variable measure and the dummy code variable to account for group differences at baseline.

Mediation analyses were conducted following MacKinnon (2008). For each mediated or indirect path in the overall model, four values (c , a , b , c') characterize the relationships among the intervention (X), mediator (M) and outcome (Y). As shown in Figure 1, the c path is the total effect of the intervention on the outcome. Ideally, in an intervention, this total effect will be significant; however this is not a requirement to proceed in examining a hypothesized mediation effect. The a path in the model is the relation of intervention X to mediator M . The b path is the relation of mediator M to outcome Y . An assumption of mediation analysis is that a mediator is an intermediate variable in a causal process. A test of the action theory, whether the a path is significant, determines whether an intervention was successful at changing a mediator, or intermediate outcome. A failure in the action theory would suggest that a revised intervention should include additional or stronger components targeting a specific mediator. A test of the conceptual theory, whether the b path is significant, determines whether change in a mediator was related to change in an outcome. A failure in the conceptual theory might suggest that the underlying theoretical assumptions were incorrect or more likely, that the outcomes were mediated by other unmeasured mediating or intermediate variables. The product of the a and b paths, ab , is the mediated effect, or the part of the total program effect transmitted through a particular mediator. Statistical significance of the ab estimate was used to evaluate the statistical evidence of mediation. The c' path ($c' = c - ab$) is the direct effect of the intervention X on outcome Y not transmitted through the mediator. The a , b , and c' paths are reported for the final model. The ab path and corresponding test of significance based on asymmetric confidence limits are also reported.

Results

Attrition Analyses

Similar rates of attrition were observed between the team condition (20%) and control condition (17%). Analyses included all participants, even those missing at post-test to control for baseline differences between those who were retained and those who were not retained.

Baseline Equivalence

Means and standard deviations for participants in the team and control conditions are reported for all constructs at pre-test (Table 3). Baseline equivalence for team and control participants was tested for all ten model constructs. The groups were found to be equivalent on all but one construct. Team participants had a significantly higher pre-test level of exercise support ($M = 3.27$ $sd = 1.54$) than did control participants ($M = 2.79$, $sd = 1.49$; $t_{(394)} = 3.07$, $p < .01$). Pre-test exercise support as well as all other pre-test measures was included in analyses to control for differences between groups at baseline.

Mediated Effects

For each outcome, two to five mediated effects were hypothesized. Figure 3 shows the overall model containing the PHLAME intervention, the five post-test mediators, and the four post-test outcomes. Paths that were statistically significant are depicted in bold. Figure 3 provides the unstandardized path estimates and corresponding standard errors for the model. This model fit the data well ($\chi^2_{(82)} = 136.914$, $CFI = .950$, $RMSEA = .041$, $SRMR = .048$). To obtain an estimate of each mediated effect, the estimates of the a and b paths were multiplied. As a test of significance, 95% asymmetric confidence limits for each mediated effect were calculated in PRODCLIN using estimates and standard errors of the paths. A confidence interval within the lower confidence limit (LCL) and upper confidence limit (UCL) that does not contain zero indicates that the effect is significant at an alpha level of .05.

Fruit consumption—Three mediators of the effect of the intervention on fruit consumption were hypothesized. First, a mediated effect of the intervention through knowledge of fruit and vegetable benefits on fruit consumption was significant ($ab = .200$, $LCL = .084$, $UCL = .344$). This supported the hypothesis that the intervention increased knowledge of fruit and vegetable benefits which in turn increased fruit consumption. The mediated effect of the intervention through personally monitoring diet on fruit consumption was not significant ($ab = .025$, $LCL = -.005$, $UCL = .073$). An increase in personally monitoring food was significantly related to an increase in fruit consumption, however, the intervention did not significantly increase personally monitoring food. The third mediated effect of the intervention through dietary coworker norms on fruit consumption was not significant ($ab = .050$, $LCL = -.030$, $UCL = .160$). The intervention did improve dietary coworker norms, however, the change in coworker norms was not significantly related to a change in fruit consumption.

Vegetable consumption—Three mediators of the effect of the intervention on vegetable consumption were hypothesized. First, a mediated effect of the intervention through knowledge of fruit and vegetable benefits on vegetable consumption was not significant ($ab = .047$, $LCL = -.029$, $UCL = .138$). Although the intervention increased knowledge of fruit and vegetable benefits, this increased knowledge of benefits did not significantly relate to a change in vegetable consumption. The mediated effect of the intervention through personally monitoring diet on vegetable consumption was not significant ($ab = .018$, $LCL = -.009$, $UCL = .063$). Neither path was significant. The third mediated effect of the

intervention through dietary coworker norms on vegetable consumption was significant ($ab = .092$, $LCL = .019$, $UCL = .189$). This supports the hypothesis that the intervention improved coworker dietary norms which in turn lead to an increase in vegetable consumption.

Self-reported exercise—There were two hypothesized mediated effects of the intervention on self-reported exercise. Neither the path through knowledge of exercise benefits ($ab = .007$, $LCL = -.010$, $UCL = .028$) or the path through exercise support ($ab = .019$, $LCL = -.003$, $UCL = .049$) was significant. Although changes in both mediators were related to changes in self-reported exercise, the intervention did not significantly change either mediator.

VO2 max—There were two hypothesized mediated effects of the intervention on VO2 max. Neither the path through knowledge of exercise benefits ($ab = .055$, $LCL = -.085$, $UCL = .231$) or the path through exercise support ($ab = -.027$, $LCL = -.141$, $UCL = .060$) were significant. Although a change in knowledge of exercise benefits was related to a change in VO2 max, the intervention did not significantly improve knowledge of exercise benefits.

Discussion

The PHLAME intervention had significant direct and indirect effects on targeted outcomes. In addition to overall effects on outcomes, support was found for parts of the action and conceptual theories. For some hypothesized mediated effects, support was found for the action theory (the intervention changed the mediator) but not for the conceptual theory (the mediator was not significantly related to the outcome). In other hypothesized mediated effects, support was found for the conceptual theory but not the action theory. Understanding the results of the study at this level of analysis informs future interventions in a more substantial way than overall treatment effects alone. Mediation analyses give insight into which mediators should be targeted more effectively and which activities may be omitted. In this way interventions may be strengthened and made more parsimonious.

Support for the action theory was found in that knowledge of fruit and vegetable benefits and dietary coworker norms were significantly improved in the team intervention condition as compared to the control condition. Firefighters share in meal preparation and potentially health and wellness activities given the long shifts that they work together. This perhaps made the norms and support of coworkers especially important for this type of work group. The beliefs about the benefits of fruits and vegetables and the existing coworker norms in fire stations before the team program were implemented did not promote healthy behaviors and were such that they could be improved upon. Personally monitoring diet, knowledge of exercise benefits and exercise support were not improved significantly in the team intervention condition as compared to the control condition. This indicates a failure of the action theory and suggests that activities targeting these mediators should be strengthened. An examination of the means in Table 3 shows that knowledge of exercise benefits was quite high in both the team and control groups before the program began. Therefore participants may not have been able to increase their knowledge of exercise benefits because they were already aware of the many benefits. It is also possible that not all hypothesized paths were supported given the unique work environment experienced by firefighters. Firefighters are one of the few occupational groups that work 24 and sometimes 48 hour shifts. This could lead to chronic sleep deprivation and fatigue that may affect decisions firefighters make about their health behaviors. Sleep deprivation that comes with shift work has been shown to be related to poorer health outcomes (Elliot & Kuehl, 2007). Perhaps because of fatigue firefighters chose not to closely monitor their dietary intake or exercise with coworkers any more than they were doing before the program.

Support for the conceptual theory was found as all mediators were related to one or more outcomes. Not all hypothesized relations between mediators and outcomes, however, were found. Increases in knowledge of fruit and vegetable benefits and personally monitoring food intake were related to an increase in fruit consumption. An increase in dietary coworker norms was related to an increase in vegetable consumption. Increases in knowledge of exercise benefits and exercise support from coworkers were related to an increase in exercise behavior. Finally, an increase in knowledge of exercise benefits was related to an increase in VO2max.

A direct effect of the intervention on fruit consumption remained when hypothesized mediators were included in the model. This suggests that the program had an effect on fruit consumption through some other unmodeled pathway not involving knowledge of benefits, monitoring of food intake, or coworker norms. No other direct effects of the intervention on targeted outcomes were significant indicating that any significant effects of the intervention on these outcomes are captured within modeled mediated pathways.

The PHLAME intervention was delivered in a team setting because of the past success of other team-based interventions and because of the team environment that is innate to the firefighter workplace. Both the high school sport team-centered drug prevention programs ATLAS (Goldberg et al., 2000) and ATHENA (Elliot et al., 2004, 2006, 2008; Ranby et al., 2009) used team settings to successfully deliver harm reduction and health promotion interventions. These programs involved teams with shared commitments, goals, and mutual accountability as well as social and task cohesion, much like the teams of firefighters. This team setting is important as learning may be improved when small groups of peers engage in intervention activities together. Additionally, social norms of this peer group may shift to value more healthy behaviors, facilitating participants' success at changing their own behaviors.

The final model for the relations in Figure 3 is our best summary of prior theoretical predictions for relations among variables. There are several limitations to our results including the possible existence of alternative models that may fit the data as well or better. Establishing true mediating mechanisms is challenging especially for relations between the mediator and the outcome variables because the mediating variable is not directly randomized but is affected by the extent to which participants self-select their level of the mediator. For example, our model specifies relations from mediators to outcomes but outcomes may in fact predict the mediators. Omitted variables may also explain mediation relations. For some variables such as knowledge of the benefits of fruit and vegetables as a mediator for actual fruit and vegetable intake, the relations may be more easily justified. Even in this case however, and in other cases, there are additional omitted variables that may explain observed results.

These analyses are limited in that mediators and outcomes were considered at only one measurement time following the intervention. Therefore the changes in mediators and changes in outcomes happened concurrently. If the changes in mediators were measured before the changes in outcomes, the argument for causality may be strengthened. Even stronger evidence for the causal link between mediators and outcomes could be achieved through an experimental design in which mediators were directly manipulated and outcomes were subsequently tested. For example, one underlying theory in the PHLAME intervention was that by participating in the program with co-workers, participants would be more likely to receive encouragement for exercise and offers to exercise together from their coworkers. This increase in coworker support for exercise was hypothesized to lead to more participant exercise. A study in which people are randomly assigned to offer support for exercise or not

would provide more evidence for the effect of coworker exercise support on participant's exercise.

The entire pattern of results, with some mediators showing statistical evidence of mediation and others not showing evidence for mediation adds credibility to the final model and informs the body of prevention science. Nevertheless, the identification of mediation processes requires a program of research with replication and extension studies, careful research design, along with evidence from other domains including qualitative analysis. For example, if knowledge of benefits of fruit and vegetable intake is a mediator of actual fruit consumption, then a study that enhances knowledge of fruit and vegetable benefits even more should lead to greater increases in fruit intake. Our goal in this manuscript was to generate the best evidence from our data, regarding the way in which mediators lead to change in outcome measures. Attaining this goal is improved when considering what constructs or potential mediators are related to the targeted outcome, the conceptual theory, and how each mediator will be changed by the intervention, the action theory.

Firefighters could benefit from departments adopting health promotion programs given that the majority of fire departments do not currently offer health promotion programs (Fahy, 2005). Mediation analyses testing the conceptual theory show that knowledge of the benefits of fruit and vegetables consumption and exercise are related to those behaviors. Further, social support from coworkers for exercise and healthier eating habits (dietary norms) of coworkers were also related to behavior. Therefore, fire stations should emphasize the benefits of healthy diet and regular physical activity, while encouraging behavior change by teams of coworkers. Because the fire station work environment is characterized by little turn over and close coworker bonds, implementing health interventions within shifts at a fire station, rather than with individuals, may be especially beneficial.

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Figure 1.
Diagram of single mediator model.

Figure 2.
CONSORT diagram showing participation in PHLAME.

Figure 3.

Full Mediation Model. Post-test constructs are depicted. All constructs were predicted by their corresponding pre-test score. Model fit the data well ($\chi^2_{(82)} = 136.914$, CFI = .950, RMSEA = .041, SRMR = .048). Unstandardized path estimates and standard errors are reported. Correlations among mediators are depicted in table at left. Correlations among outcomes are depicted in table at right. All bold paths are statistically significant. * $p < .05$, ** $p < .01$, *** $p < .001$.

Table 1**Action Theory of PHLAME Team Intervention**

Action Theory Relating Intervention Activities to Hypothesized Mediators	
Team Sessions and Example Activities	Hypothesized Mediators
1, 3, 6, 7, 11 Health jeopardy game Fruits & vegetables card game Old fire fighter game	Knowledge of benefits fruits, vegetables and healthy diet
3, 4, 6, 11 Self-assessment current diet Five alarm call to good health monitoring game Fruits and vegetable medley game	Personally monitoring diet
3, 4, 5, 11 Teammates as trainers Five alarm call to good health monitoring game Extreme fast food makeover	Dietary co-worker norms (participate with me in activities)
3, 5, 8, 11 Health jeopardy game Endurance for fire fighters Energy balance game	Knowledge benefits of physical activity
3, 4, 5, 9, 10 Teammates as trainers Five alarm call to good health monitoring game Pedometer challenge	Exercise support (encourage me to be physically active)

Note. Implicit in the work structure is that the healthy attitudes and behaviors would be modeled and reinforced at times outside of the team sessions.

Table 2

Conceptual Theory of PHLAME Team Intervention

Conceptual Theory Relating Hypothesized Mediators to Outcomes	
Hypothesized Mediators	Primary Outcomes
Knowledge of fruits benefits ^Φ Personally monitoring diet ^Ψ Dietary co-worker norms ^Ψ	Fruit consumption
Knowledge of vegetable benefits ^Φ Personally monitoring diet ^Ψ Dietary co-worker norms ^Ψ	Vegetable consumption
Knowledge of exercise benefits ^Φ Exercise support ^Ψ	Self-reported physical activity
Knowledge of exercise benefits ^Φ Exercise support ^Ψ	Measured fitness (maximum oxygen uptake / VO2max)

Note. Superscripts denote whether relation was hypothesized based on the ^Φ Health Belief Model or ^Ψ Social Cognitive Theory

Table 3
Constructs, Ranges, Reliabilities and Comparison of Pre-Test Means between Team and Control

Construct	Range	Cronbach's α		Mean (SD)	
		Pre-test	Post-test	Team	Control
Knowledge fruit/vegetable benefits	1-7	.896	.910	5.54 (1.06)	5.58 (0.94)
Personally monitoring diet	1-7	-- ^a	-- ^a	3.13 (1.59)	3.39 (1.73)
Dietary coworker norms	1-6	.720	.725	3.23 (.079)	3.22 (.089)
Knowledge of exercise benefits	1-7	.898	.932	6.00 (0.90)	5.91 (0.93)
Exercise support	1-7	.888	.881	3.27 ^b (1.54)	2.79 ^b (1.49)
Fruit consumption (servings per day)	0-15	-- ^a	-- ^a	2.15 (1.92)	1.93 (2.00)
Vegetable consumption (servings per day)	0-14	-- ^a	-- ^a	3.60 (2.14)	3.67 (2.10)
Self-reported exercise	0-7	.872	.893	2.87 (1.53)	2.62 (1.40)
VO2 max	20-61	-- ^a	-- ^a	38.08 (7.47)	37.40 (6.57)

Note. Intervention and control participants did not differ on any baseline measure of mediators or outcomes except for current exercise support.

^a Cronbach's α reliability not computed because the construct was not formed as a mean of items.

^b Intervention participants had a significantly higher pre-test level of exercise support ($t(394) = 3.07, p < .01$).