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Intervention-mediated effects for adult physical activity: A latent growth curve analysis

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Abstract

Data from two randomized clinical trials (RCT) were used to examine the extent to which a health promotion intervention affected changes in growth trajectories of psychosocial constructs and if so, whether these constructs in turn explained changes in physical activity (PA). PA and psychosocial measures on 842 overweight adults in the United States were collected in two RCTs evaluating Internet-based behavior change interventions with assessments at baseline, 6 and 12 months. A physical activity latent variable at 12 months was created using indicators of self-reported walking and leisure time activities. Intervention-mediated effects on PA at 12 months were found via latent growth curves representing self-efficacy and behavioral strategies, where increasing growth curves across time were associated with higher PA values at 12 months. These findings provide some evidence that web-based self-help intervention programs worked through targeted behavior change constructs to influence physical activity levels in overweight adults.

Keywords

Physical Activity; Randomized Clinical Trial; Latent Growth Curve; Adult; USA; interventions; internet

The American College of Sports Medicine, the Centers for Disease Control and Prevention, and the Surgeon General of the United States recommended at least 30 minutes of moderate-intensity physical activity (PA) on most days of the week. However, national estimates indicate that only slightly more than half of the population engages in leisure time PA on a daily basis (U.S. Department of Health and Human Services, 2000) and 25.4% of adults do not engage in any PA (Centers for Disease Control, 2005). These estimates are particularly troublesome in light of recent evidence showing that regular PA is inversely associated with cardiovascular and cancer morbidity and mortality (e.g., Meyerhardt, Govannucci, Holmes, Chan, Chan, Colditz, et al., 2006), as well as reductions in the risk of diabetes (Kriska, 2003). Because of the beneficial effects of PA, results from intervention-based mediation are critical for the identification of more effective ways/methods of health behavior change (see Baranowski, Anderson, & Carmack, 1998; Baranowski, Cullen, Nicklas, Thompson, & Baranowski, 2003). Specifically, Baranowski et al. and a recent review by Lubans, Foster, and Biddle (2008) have emphasized the importance of evaluating the effect of PA interventions on targeted psychosocial constructs to better understand the mechanisms of PA change.

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Many PA interventions were designed to impact psychosocial constructs such as self-efficacy (e.g., Stiggelbout, Hopman-Rock, Crone, Lechner, & van Mechelen, 2006), decisional balance (e.g., Bock, Marcus, Pinto, & Forsyth, 2001), behavioral strategies or processes of change (e.g., Rhodes & Plotnikoff, 2006), and social support (e.g., Boutelle, Jeffery, & French, 2004) that have been identified as correlates of PA (see also Bauman, Sallis, Dzewaltowski, & Owen, 2002 for a review). Social-cognitive theory (SCT; Bandura, 1989) and the Transtheoretical Model (TTM; Prochaska & Velicer, 1997), in particular, are frequently drawn upon when designing PA interventions (Pinto, Lynn, Marcus, DePue, & Goldstein, 2001; Sallis, Calfas, Alcaraz, Gehrman, & Johnson, 1999). These theories provide a framework for understanding how environmental/contextual cues (peers, family), cognitions (pros, cons), intrapersonal skills (self-efficacy, self-regulation strategies) lead to increased (or decreased) PA. Moreover, these frameworks readily identify those variables that should be targeted by intervention programs.

Studies evaluating intervention mediated effects of psychosocial constructs on adult PA have generally been inconclusive. The strongest evidence of intervention-mediated effects has been found for self-efficacy (e.g., Lewis, Forsyth, Pinto, Bock, Roberts, & Marcus, 2006; Miller, Trost, & Brown, 2002) and cognitive (e.g., increasing knowledge, warning of risks, and committing yourself) behavioral processes of change (e.g., substituting alternatives, enlisting social support, and rewarding yourself; Lewis, Marcus, Pate, & Dunn, 2002; Lewis et al., 2006; Pinto et al., 2001; Napolitano et al., 2008; Sallis et al., 1999). There is some (weaker) support for intervention-mediation effects for social support (e.g., Cerin, Taylor, Leslie, & Owen, 2006; Barrera, Strycker, MacKinnon, & Toobert, 2008) and decisional balance (e.g., Marcus, Bock, Pinto, Forsyth, Roberts, & Traficante, 1998). In sum, evidence that interventions affect behavioral and interpersonal factors (e.g., self-regulatory strategies, social support, decisional balance), which ultimately influence PA, exists but has not been consistent across studies.

The current study used latent growth curve analysis (LGCA) to examine intervention-mediated effects of PA in the context of health behavior change interventions for adults (the Patient-centered Assessment and Counseling for Exercise + Nutrition [PACE+], (Calfas, Patrick, Hagler, Norman, Zabinski, & Sallis, 2006; Calfas, Patrick, Norman, Zabinski, Dillon, & Rock, 2007). By examining growth curves of target mediators that increase or decrease, and are subsequently associated with PA at a later time-point, one can identify the psychosocial variables that are effective in adoption and maintenance of physical activity levels (Brawley, Rejeski, & King, 2003). Studies that have used such analyses to examine PA as an outcome have either not included an intervention as the target antecedent variable (Duncan & McAuley, 1993), or did not find significant relations between the growth curve of the putative mediator (social support) and the target outcome (e.g., calorie expenditure; see Barrera et al., 2008).

The purpose of the current study was twofold. First, the growth trajectories for several psychosocial variables (behavior change strategies, pros, cons, self-efficacy, social support) were evaluated to determine if consistent increases/decreases across time were evident for each target variable, and whether or not growth trajectories differed as a function of being randomized to an intervention group. Second, a formal test for mediation effects of the intervention on PA was examined. Specifically, we tested whether or not the relationship between the intervention and PA at the 1-year endpoint was mediated by the growth trajectories of the psychosocial variables.

Method

Participants

Women and men enrolled in separate but similar randomized controlled trials of health promotion and weight control interventions targeting physical activity and multiple dietary

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outcomes (Intervention n = 429, Control n= 413). The women's trial took place between July 2002 and August 2005, while the men's trial occurred between February 2004 and May 2007. The average age of adults in the combined sample was 42.61 (*SD* = 8.42) years. The race/ethnicity distribution of the sample was 66.2% white non-Hispanic, 19.2% Hispanic, 6.2% African-American, 3.7% Asian or Pacific Islander, and 14.7% multi-ethnic or other race/ethnicities. The combined sample was 47.6% female with a majority being married (68.7%). Highest education level was distributed as 33% some college or less, 27.4% Bachelor's degree, 27.7% graduate or professional training or degree, and 11.9% some high school, high school graduate, or technical/trade school graduate.

In both studies participants were recruited from within San Diego County, California. Women were recruited through their primary care providers at seven different clinic sites, but randomized to condition at the individual level. Participating providers sent letters to their female patients within the eligible age range informing them that they may be contacted to participate in a research study. Men were recruited from the community through newspaper and radio advertisements and posted fliers. Eligibility criteria for both studies included being age 18 to 55, having a BMI between 25 and 40, having Internet computer access, able to read and speak English, and able to engage in moderate physical activity. Additionally, women were not eligible if pregnant or planning to be pregnant in the next 2 years. All study protocols were approved by institutional review boards for the protection of human subjects at San Diego State University and University of California, San Diego, and all participants provided informed consent.

Interventions

While the male and female interventions were largely similar, they were not identical. A full description of the interventions is now provided. The 1-year interventions were designed to improve physical activity and diet behaviors believed to promote weight loss and reduce risk of chronic diseases. Intervention content was based on SCT (Bandura, 1986) and the Transtheoretical Model (Prochaska & Velicer, 1997). Both interventions used websites to deliver information content and interactive tools for guided goal setting and self-monitoring. Information was delivered as a set of monthly topics related to physical activity and nutrition (e.g., stretching, injury prevention, reading food labels, dining out). Both interventions introduced a monthly behavior skill to apply toward reaching the targeted behavior goals. Behavior skills consisted of: a) goal setting (setting realistic goals), b) self-monitoring, c) making changes enjoyable, d) stimulus control, e) thinking about long-term benefits, f) identifying barriers, g) using positive self-talk, h) rewarding yourself, i) getting support, j) weighing the pros and cons of change, k) relapse prevention planning. The women's intervention was named 'Women in Balance' and emphasized making positive behavior changes while balancing family, work and other responsibilities. The men's intervention was named 'Men in Motion' and was designed to give men a 'tool box' of resources for behavior self-management. In both studies participants were randomized to either the PACE intervention condition or a wait-list control group, where participants could cross-over and receive the intervention after completing the 12-month assessment.

In the women's study the target behaviors were to increase moderate and vigorous physical activity to 150 min/wk, increase fruit and vegetable intake, increase dietary fiber, and decrease total fat. The intervention began with an online computer assessment of initial status on the target behaviors and guided goal setting. Printed goals were delivered to the participant's primary care provider prior to a scheduled visit. Providers were trained to give brief 3 to 5 minute counseling on diet and activity using the computer printout to guide the counseling session. Following the provider visit, women were given access to the intervention website that provided a monthly topic, application of a behavior change skill (e.g., self-monitoring,

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identifying barriers) and the review of current behavior goal setting and setting new goals. Email correspondence was initiated by the case manager each month and four 15–20 minute telephone calls were scheduled over the 12-month period. The telephone calls followed a semi-structured format where case managers helped participants assess their goals and progress, trouble-shoot barriers, and answer questions.

In the men's study the target behavior goals included increasing steps per day to at least 10,000 (5–7 d/wk), participating in strength training two times per week, increasing fruit and vegetable intake and whole grains, and decrease saturated fat intake. Participants were encouraged to start with a realistic goal and work up to meeting the program goals. The intervention had three components. First, a computer program was completed by participants to assess their initial status on each of the five behavior targets. Then the computer guided them to select and set goals in each area. Participants were encouraged but not required to take a printed copy of their goals to their provider and discuss the goals as a means of weight loss. Over the next year, participants completed monthly web-based activities including learning about and applying a new behavioral skill and reading physical activity and diet topics. Tip sheets, topical news items and archived content were all available online and content was updated weekly. Participants were encouraged to log on weekly to report their weight and progress on their goals and to set new goals. Men were given pedometers to assess daily steps and were encouraged to input the data on the website for tracking purposes. Finally, case managers had occasional email and phone contact with the men primarily to facilitate interaction with the website and trouble-shoot technical difficulties.

Participants in both studies completed the same measures. The baseline and 12-month survey measures on a computer in a quiet setting at the study research office. For the 6-month assessment, participants were emailed an Internet web address with a secure link to complete the 6-month assessment within a one month window. Participants received $15, $20, and $40 dollars for compensation for travel and completing measurements at baseline, 6-months, and 12-months, respectively.

Measures

Physical Activity—Participants completed the International Physical Activity Questionnaire (IPAQ) long form to indicate physical activity engagement over the previous seven days in four domains, including leisure time, occupation, transportation, and home. This questionnaire was evaluated in a 12-country study and found to have test-retest reliability and validity (compared to accelerometers) comparable to other questionnaires (Craig, Marshall, Sjöström, Bauman, Booth, Ainsworth, et al., 2003). Reported frequency (days per week during last 7 days) and duration (hours and minutes per day) for leisure vigorous (8 METS), moderate (4 METS), and walking (3.3 METS) activity were used to derive a weekly total MET-min per week of leisure-time physical activity. Walking MET-min per week combined job-related walking and walking for transport (3.3 METS).

Psychosocial Measures—A survey battery was developed that included items assessing psychosocial constructs that the intervention was designed to impact, including behavior change strategies, pros and cons of change, self-efficacy, and social support.

Behavior Change Strategies—This 15-item scale that included cognitive (e.g., think about the benefits, make back-up plans) and behavioral (e.g., put reminders around my home, keep track of my activity) strategies. The change strategies items were based on a previously developed scale (Saelens, Gehrman, Sallis, Calfas, Sarkin, & Caparosa, 2000) with several items similar to the processes of change from the transtheoretical model (Prochaska & Velicer,

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1997). Participants responded to each item on a 5-point Likert scale ranging from 1 (never) to 5 (very often). The composite scale had an internal consistency coefficient of α = .89 at baseline.

Decisional Balance—Decisional balance comprises two constructs called the Pros and Cons of change that address cognitive and motivational aspects of human decision-making (Velicer, DiClemente, Prochaska, & Brandenburg, 1985). For the current study, the pros and cons of physical activity included some items from a previously developed instrument (Marcus, Rakowski, & Rossi, 1992) with some a new items to create two 5-item scales. Participants rated the importance of each item on a 5-point Likert scale ranging from 1 (not at all important) to 5 (extremely important). Internal consistency for the pros scale was α = .72, and α = .58 for the cons scale at baseline.

Self-efficacy—Participants completed a 5-item measure of self-efficacy pertaining to engaging in activity in specific situations (e.g., tired, bad mood, don't have time, on vacation, weather is bad) sharing similar items to a previously developed measure (Marcus et al. 1992). Participants responded to each item on a 5-point Likert scale ranging from 1 (not at all confident) to 5 (extremely confident). Internal consistency for the self-efficacy scale was α = . 76 at baseline.

Social Support—Social support for physical activity was assessed with a 5-item scale. Five items assessed how often, in the past 30 days, family or friends did supportive actions (e.g., encourage, discuss, remind, share ideas, do physical activity with you) related to physical activity. Item content and response format were based on previously developed scales (Sallis, Grossman, Pinski, Patterson, & Nader 1987). Internal consistency for the scale was α =.90 at baseline.

Statistical Analyses

To examine the longitudinal relations among the study variables, LCGA was conducted (see, e.g., Duncan, Duncan, Stryker, & Chaumeton, 2007; Duncan, Duncan, Stryker, Li, & Alpert, 1999). The analysis models growth trajectories (curves) for variables over time. Scores for the psychosocial variables at baseline, 6-month follow-up, and 12-month follow-up were used as observed variables. For each model the latent intercept variable was centered relative to scores at the first time-point (i.e., baseline) so that the intercept represented the initial status of the growth curve. The linear slope represented the functional form of the growth trajectory across the time-points. A linear slope could not be fit to the physical activity measures (walking, leisure time activities). For this reason, physical activity at the 12-month follow-up was assessed as the target *distal* outcome. A physical activity latent variable was created at both baseline and at the 12-month follow-up using walking and leisure time activities as indicators (observed variables). All analyses were based on intent to treat.

A series of preliminary models was tested in the following sequence. First, to determine the growth trajectories for each psychosocial variable, unconditional linear growth models were initially fit tested. Second, conditional growth models predicting the psychosocial growth trajectories with the intervention variable were evaluated (testing the antecedent to mediator relationship). Third, conditional growth models predicting activity at the 12-month follow-up with the psychosocial growth trajectories were evaluated (testing the mediator to outcome relationship). Fourth, a structural equation model was specified predicting activity at the 12-month follow-up with the intervention variable (testing the antecedent to outcome relationship). Based on these preliminary models, formal mediation models were specified to determine whether or not the growth trajectory of each psychosocial variable mediated the relationship between the intervention variable and the latent variable representing activity at the 12-months. MacKinnon's asymmetric confidence interval was calculated to determine if

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the mediated effect was statistically significant (see MacKinnon, Fritz, Williams, & Lockwood, 2007). A mediated effect is supported if the 95% confidence interval does not contain 0, which suggests that intervention influenced the trajectory of the mediator, which, in turn, was associated with activity. Age, gender, and education were used as covariates in these analyses.

Overall model fit was determined using the recommendations of Bentler (2007; see also Wu, West, & Taylor, 2009 for a discussion that is specific to growth curve models). In the current study, the (a) the Comparative Fit Index (CFI; Bentler, 1990), with values greater than .95 indicating reasonable model fit and values greater than .90 indicating a plausible model; and (b) the Standardized Root Mean Residual (SRMR; Hu & Bentler, 1999), with values less than .05 indicating reasonable model fit and values less than .08 indicating a plausible model. The likelihood ratio $\chi 2$ is also reported for completeness.

For all models the maximum likelihood missing data procedure employed by MPlus (Muthén & Muthén 2006) was used. This maximum likelihood procedure uses all available data from each participant and assumes that data are missing at random. Ten missing data patterns were observed when the psychosocial variables and the activity outcomes were jointly considered. Five hundred participants had complete data at all three time-points and 342 participants had some missing data. Analyses of variance and chi-square tests of independence were used to determine if missing data were related to demographic variables. Statistically significant differences were found for age, $F(1,838) = 5.35$, $p = .021$, $\eta^2 = .006$, education, $F(1,838) = 5.98$, $p = .015$, $\eta^2 = .007$, and gender, $\chi^2 = 3.84$, p = .050, $\Phi = .07$, as a function of missing data. Those who had missing data were younger ($M = 41.77$ vs. 43.14), less educated ($M_{z\text{-}score} = -.10$ vs. .07), and were more likely to be male (42.6% vs. 36.2). Therefore, these three variables were incorporated into all models as covariates by specifying direct paths from each variable to each latent growth factor and the PA latent variable at 12-month follow-up.

Results

Means and standard deviations for all target study variables are presented in Table 1.

Preliminary Models

Preliminary multiple groups analyses were conducted to determine if the male and female data could be pooled. To determine if the relationship between the intervention variable and (a) physical activity at 12 months and (b) the growth curves for the five psychosocial mediators was invariant across males and females, the paths representing these effects were set to equivalence. These analyses revealed that the relationship between the intervention variable and the physical activity latent variable at 12-months was statistically equivalent between males and females ($p > .05$). Moreover, it revealed no statistically significant differences for the relationship between (a) the intervention variable and the 5 growth curves representing the putative psychosocial mediators and (b) between the mediators and the physical activity latent variable (all *ps* > .05). Overall model fit for these constrained models were similar to those based on the pooled data reported below. All subsequent analyses are based on pooled data.

A preliminary model tested the direct relation of the intervention variable on the latent physical activity variable at the 12-months. This model fit well both statistically and descriptively, $\chi^2(df=3) = 6.64$, $p = .08$, CFI = .969, SRMR = .017. The intervention variable was significantly associated with activity at the 12-months (B = .199, $p = .029$, $R^2 = .38$), while adjusting for activity at baseline (B = .607, $p < .001$, $\beta = .59$). Individuals in the intervention group had significantly higher activity values at the 12-month follow-up relative to the control group.

Overall model fit information and estimates of the growth trajectories for each psychosocial variable are presented in Table 2. All unconditional growth models fit well according to the

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descriptive fit indices. None of the growth trajectories was statistically significant. However, each growth trajectory did exhibit statistically significant variability (all *p*s < .05), with the exception of the cons growth trajectory.

To evaluate the direct relation between the intervention variable (the antecedent) and the psychosocial growth trajectories a series of conditional growth models were tested (see Table 3a). All models fit well according to the descriptive fit indices. Intervention effects were found in the prediction of both the strategies ($R^2 = 0.07$) and self-efficacy growth trajectories ($R^2 = 0.05$), respectively. Individuals in the intervention group had significantly stronger (and positive) growth trajectories for both strategies and self-efficacy relative to the control group.

To evaluate the direct relation (association) between the psychosocial growth trajectories and the latent variable representing activity at the 12-month follow-up a series of conditional models were tested (see Table 3b). All models fit reasonable well according to the descriptive fit indices. The factor loadings for the activity latent variables were all statistically significant and relatively large (standardized loadings ranged from .46 to .62). Positive associations were found between the growth trajectories for strategies, self-efficacy, and support with activity at the 12-months. Positive slope values for these three psychosocial growth trajectories were associated with higher activity at 12 months (controlling for activity at baseline). This indicates that individuals with increased strategy use, self-efficacy, and support over time had higher activity values at 12 months.

Mediation Models

In light of the preliminary models, formal mediation could only be tested for the behavior strategies and self-efficacy growth trajectories, because statistically significant antecedent to mediator and mediator to outcome relations were found for both psychosocial variables. The mediation model fit for the strategies mediator fit reasonably well according to the descriptive fit indices, $\chi^2(df=23) = 159.22$, $p < .001$, CFI = .907, SRMR = .049. Parameter estimates are presented in Figure 1. The compound paths from the intervention variable to the strategies growth trajectory to activity at the 12-months were all statistically significant. Moreover, MacKinnon's asymmetric confidence interval formally established mediation (95% asymmetric CI = 0.11 to 0.40). Those in the intervention group had stronger and positive growth trajectories for strategies relative to the control group. These growth trajectories, then, were positively associated with the activity at the 12-months. In addition, the direct effect from the intervention variable to activity was not statistically significant, suggesting that the strategies growth trajectory completely mediated the intervention-activity relationship. Although not shown in Figure 1, gender was positively related to activity (B = 0.28, $p = .004$) and the growth trajectory for strategies (B =−.05, $p = .041$). Males reported higher activity at the 12-months relative to females, but females had stronger strategies growth trajectories than males. Education and age were not related to the strategies growth trajectory or latent activity variable (all *p*s > .05).

The mediation model for the self-efficacy mediator fit reasonably well according to the descriptive fit indices, $\chi^2(df=23) = 117.50$, $p < .001$, CFI = .917, SRMR = .043. Parameter estimates are presented in Figure 2. The compound paths from the intervention variable to the self-efficacy growth trajectory to activity at the 12-months were all statistically significant. Moreover, MacKinnon's asymmetric confidence interval formally established mediation (95% asymmetric CI = 0.04 to 0.31). Those in the intervention group had stronger and positive growth trajectories for self-efficacy relative to the control group. These growth trajectories, then, were positively associated with the activity at the 12-months. In addition, the direct effect from the intervention variable to activity at the 12-month follow-up was no longer statistically significant, suggesting that the self-efficacy growth trajectory completely mediated the intervention-activity relationship. Although not shown in Figure 2, gender was positively

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related to activity (B = 0.23, p = .026), with males reporting higher activity at the 12-month follow-up relative to females. Education and age were not related to the strategies growth trajectory or latent activity variable (all ps > .05).

Discussion

The current study used latent growth curve analysis to assess the relationships between psychosocial variables and physical activity in the context of an intervention study. Statistically significant and positive relationships between the growth trajectories of specific psychosocial variables (behavioral change strategies, self-efficacy, and social support) and activity at 12 months were evident. Moreover, intervention-mediated effects were noted between the PACE intervention and activity. Those individuals in the intervention group (relative to the control group) had significantly stronger and more positive growth trajectories for behavioral strategies and self-efficacy, also had higher activity values at 12-months.

It is notable that use of behavior change strategies and self-efficacy were the strongest mediators of physical activity. The latent growth model depicting the intervention working through behavior change strategies and self-efficacy to increase physical activity supports theory-based hypotheses and is consistent with prior evidence. The causal direction specified in the model is logical because the behavior change strategy and self-efficacy items were specifically developed to represent the content of the PACE intervention that was based on social cognitive theory (Bandura, 1989) and the Transtheoretical Model (Prochaska & Velicer, 1997). However, our measures were not sensitive enough to determine specifically what aspects of the intervention influenced changes in self-efficacy and increased used of change strategies. We can speculate that participants that used the website to set realistic behavior goals increased their self-efficacy when they achieved those goals, which in turn, gave them the confidence to set new and more challenging goals.

Previous intervention studies with adults have also found intervention-mediated effects for both self-efficacy (Lewis et al., 2006; McAuley, Jerome, Elavsky, Marquez, & Ramsey, 2003; Miller et al., 2002) and behavioral strategies or processes of change (e.g., Lewis et al., 2006; Pinto et al., 2001; Napolitano et al., 2008; Sallis et al., 1999). The findings support a conclusion that teaching and promoting use of behavior change strategies and increasing self-efficacy are effective intervention components; the analyses did not rule out that change in activity influenced changes in the use of behavior change strategies and self-efficacy since the measurement of both processes are internal to the individual (Weinstein, 2007; Willett & Singer, 2003). Both processes mutually influencing activity (and each other) would be consistent with reciprocal determinism proposed in social cognitive and ecological theories (Bandura, 1989).

That intervention-mediated effects were *not* found via the social support might appear curious in light of recent findings predicting activity (Cerin et al., 2006; Dzator, Hendrie, Burke, Bianguilio, Gillam, Beilin, et al., 2004; Barrera et al., 2008) and the general success of social support interventions (Hogan, Linden, & Najarian, 2002). The PACE intervention did not significantly increase the growth trajectory for social support relative to the control group. However, supplementary analyses showed that the intervention did have a statistically significant and positive influence on social support at 6 months (B = .20, p = .005) but *not* on social support at 12 months (B = −.02, p = .21). This suggests that the intervention was effective in increasing activity in the short-term but not the long-term. That the social support growth trajectory was positively associated with the growth trajectories for both self-efficacy and behavioral strategies, (rs = .72 and .66, respectively; ps < .001), combined with the social support trajectory being associated with activity at 12 months, suggests that social support is

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important in the maintenance of activity in the long-term (Rothman, Baldwin, & Hertel, 2004), even though not directly influenced by the PACE+ intervention.

The strengths of the present study include a large and diverse sample of adults who participated in two similar randomized intervention trials. This design with three measurement points over a 12-month period allowed for a rare test of whether a health behavior change intervention operated through theoretically-derived psychosocial mediators to affect physical activity behavior (Baranowski et al., 1998). The study included tests of four psychosocial constructs and used LGCA, a 'state of the science' statistical approach to assessing change and predictors of change (Duncan, Duncan, & Strycker, 2005).

There are several limitations to this study. First, causal inferences cannot be formally made for the behavioral strategies and self-efficacy intervention-mediated models. As noted by MacKinnon (MacKinnon et al., 2007), causal inference for the mediator-outcome relationship is tenuous when there is no randomization to the mediator. Moreover, the last time-point for the mediator variables was assessed concurrently with the target outcome at 12 months. Second, a *linear* growth model could not be fit to the activity variables across the three time-points, thus precluding the possibility of evaluating the relationship between the growth trajectories of the psychosocial mediators and activity. A non-linear model would appear to be more appropriate for PA when examining the observed means, but this possibility could not be formally explored due to the limited number of time-points. Third, activity was measured as a latent variable with two indicators representing walking and leisure time activities. While this latent variable represents the commonality among these two indicators of physical activity, and thus reduces the measurement error in this target outcome, it certainly is not entirely comparable to other estimates of physical activity. For example, both Rovniak et al. (2002) and Anderson et al. (2006) used multiple indicators of activity to represent this latent variable (stage of change measure, energy expenditure, number of activity modes for the former, and steps/day, MET hr/week for the latter). A latent variable of physical activity may mask specific relationships, as different intervention and mediated effects have been found for different outcomes (e.g., Calfas, Long, Sallis, Wooten, Prat, & Patrick, 1996; McNeill, Wyrwich, Brownson, Clark, & Kreuter, 2006).

This study is further limited by focusing primarily on intrapersonal variables. Broader models including environmental variables (Cerin, Vandelanotte, Leslie, & Merom, 2008) are certainly important for future research to fully delineate the nomological net in the prediction of activity. Direct and indirect predictors of PA have been found when intrapersonal, social-environmental, and physical environmental predictors are included in the same model (McNeill et al., 2006). Moreover, additional intrapersonal variables associated with maintenance should also be considered. Recent research has shown that positive affect (anticipated or real), satisfaction, and enjoyment of physical activity are important for adoption and maintenance of this behavior (Dunton & Vaughan, 2008; Kiviniemi, Voss-Hunke, & Seifert, 2007; McAuley et al., 2003; McAuley, Morris, Motl, Hu, Konopack, & Elavsky, 2007; Salmon, Owen, Crawford, Bauman, & Sallis, 2003). While the current study adds to the research on how psychosocial constructs relate to activity, further study of hypothesized mediating mechanisms is needed to test and refine behavior change theories that guide PA interventions.

In conclusion, this is the first study to find evidence for intervention-mediated effects using growth trajectories for putative mediator variables of physical activity. Intervention programs are generally devised to change proximal variables (e.g., psychosocial mediators), which are then expected to have effects on health outcomes of interest (West & Aiken, 1997), rather than directly act on the outcome. The PACE intervention was consistent with this reasoning. This intervention targeted cognitive and behavioral change strategies, which were then associated with activity and explained the direct effect of the intervention on activity. Moreover, these

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mediated effects were found on behavior at 12 months, contrary to most previous evaluations that found initial increases in activity to be usually short-lived (Hillsdon, Foster, & Thorogood, 2005; Marcus, Williams, Dubbert, Sallis, King, Yancey, et al., 2006). The findings support the use of mediating variable models as a framework for evaluating intervention studies that promote improvements across a variety of health behaviors and populations (Baranowski et al., 1998; Baranowski et al., 2003; Wilson, 2008).

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References

Anderson ES, Wojcik JR, Winett RA, Williams DM. Social-cognitive determinants of physical activity: The influence of social support, self-efficacy, outcome expectations, and self-regulation among participants in a church-based health promotion study. Health Psychology 2006;25:510–520. [PubMed: 16846326]

Bandura A. Human agency in social cognitive theory. American Psychologist 1989;44:1175–1184. [PubMed: 2782727]

Bandura, A. Self-efficacy: The exercise of control. New York, NY: Friedman; 1997.

Baranowski T, Anderson C, Carmack C. Mediating variable framework in physical activity interventions: How are we doing? How might we do better? American Journal of Preventive Medicine 1998;15:266–297. [PubMed: 9838973]

Baranowski T, Cullen KW, Nicklas T, Thompson D, Baranowski J. Are current health behavior change models helpful in guiding prevention of weight gain efforts? Obesity Research 2003;11:23S–43S. [PubMed: 14569036]

Barrera M Jr, Strycker LA, MacKinnon DP, Toobert DJ. Social-ecological Resources as mediators of two-year diet and physical activity outcomes in type 2 diabetes patients. Health Psychology 2008;27:S118–S125. [PubMed: 18377153]

Bauman AE, Sallis JF, Dzewaltowski DA, Owen N. Toward a better understanding of the influences on physical activity: The role of determinants, correlates, causal variables, mediators, moderators, and confounders. American Journal of Preventive Medicine 2002;23:5–14. [PubMed: 12133733]

Bentler PM. Comparative fit indexes in structural models. Psychological Bulletin 1990;107:238–246. [PubMed: 2320703]

Bentler PM. On tests and indices for evaluating structural models. Personality and Individual Differences 2007;45:825–829.

Bock BC, Marcus BH, Pinto BM, Forsyth LH. Maintenance of physical activity following an individualized motivationally tailored intervention. Annals of Behavioral Medicine 2001;23:79–87. [PubMed: 11394558]

Boutelle KN, Jeffery RW, French SA. Predictors of vigorous exercise adoption and maintenance over four years in a community sample. International Journal of Behavioral Nutrition and Physical Activity 2004;1:13. [PubMed: 15341656]

Brawley LR, Rejeski WJ, King AC. Promoting physical activity for older adults: The challenge for changing behavior. American Journal of Preventive Medicine 2003;25 Supp. 2:172–183. [PubMed: 14552942]

Calfas KJ, Long BJ, Sallis JF, Wooten WJ, Prat M, Patrick K. A controlled Trial of physician counseling to promote the adoption of physical activity. Preventive Medicine 1996;25:225–233. [PubMed: 8780999]

Calfas KJ, Patrick K, Hagler A, Norman GJ, Zabinski MF, Sallis JF. Twelve-month dietary and physical activity outcomes in ‘PACE-Women in Balance’: A primary-care and web-based intervention. Annals of Behavioral Medicine 2006;31 (suppl):S184.

Calfas KJ, Patrick K, Norman GJ, Zabinski MF, Dillon L, Rock CL. Twelve-month dietary and physical activity outcomes in ‘men-in-motion’, a web-based intervention for overweight men. Annals of Behavioral Medicine 2007;33 (suppl):S21.

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Centers for Disease Control and Prevention (CDC). Behavioral risk factor surveillance system survey data. Atlanta, GA: 2005.

Cerin E, Taylor LM, Leslie E, Owen N. Small-scale randomized control trials need more powerful methods of mediational analysis than the Baron-Kenny method. Journal of Clinical Epidemiology 2006;59:457–464. [PubMed: 16632133]

Cerin E, Vandelanotte C, Leslie E, Merom D. Recreational facilities and leisure-time physical activity: An analysis of moderators and self-efficacy as a mediator. Health Psychology 2008;27:S126–S135. [PubMed: 18377154]

Craig CL, Marshall AL, Sjöström M, Bauman AE, Booth ML, Ainsworth BE, Pratt M, Ekelund U, Yngve A, Sallis JF, Oja P. International physical activity questionnaire: 12-country reliability and validity. Medical Science and Sports Exercise 2003;35:1381–1395.

Duncan SC, Duncan TE, Strycker LA. Sources and types of social support in youth physical activity. Health Psychology 2005;24:3–10. [PubMed: 15631557]

Duncan SC, Duncan TE, Strycker LA, Chaumeton NR. A cohort-sequential latent growth model of physical activity from ages 12 to 17 years. Annals of Behavioral Medicine 2007;33:80–89. [PubMed: 17291173]

Duncan, SC.; Duncan, TE.; Strycker, LA.; Li, F.; Alpert, A. An introduction to latent variable growth curve modeling: Concepts, issues, and applications. Mahwah, NJ: Erlbaum; 1999.

Duncan TE, McAuley E. Social support and efficacy cognitions in exercise Adherence: A latent growth curve analysis. Journal of Behavioral Medicine 1993;16:199–218. [PubMed: 8315646]

Dunton GF, Vaughan E. Anticipated affective consequences of physical activity Adoption and maintenance. Health Psychology 2008;27:703–710. [PubMed: 19025265]

Dzator JA, Hendrie D, Burke V, Gianguilio N, Gillam HF, Beilin LJ, Houghton SA. A randomized trial of interactive group sessions achieved greater improvements in nutrition and physical activity at a tiny increase in cost. Journal of Clinical Epidemiology 2004;57:610–619. [PubMed: 15246129]

Hillsdon M, Foster C, Thorogood M. Interventions for promoting physical activity. Cochrane Database Systematic Review. 2005 CD003180.

Hogan BE, Linden W, Najarian B. Social support interventions: Do they work? Clinical Psychology Review 2002;22:381–440.

Hu L-T, Bentler PM. Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. Structural Equation Modeling 1999;6:1–55.

Kiviniemi MT, Voss-Hunke AM, Seifert AL. How do I feel about behavior? The interplay of affective associations with behaviors and cognitive beliefs as influences on physical activity behavior. Health Psychology 2007;26:152–158. [PubMed: 17385966]

Kriska A. Can a physically active lifestyle prevent type 2 diabetes. Exercise and Sports Science Reviews 2003;31:132–137.

Lewis BA, Forsyth LH, Pinto BM, Bock BC, Roberts M, Marcus BH. Psychosocial mediators of physical activity in a randomized controlled intervention trial. Journal of Sport & Exercise Psychology 2006;28:193–204.

Lewis BA, Marcus BH, Pate RR, Dunn AL. Psychosocial mediators of physical activity behavior among adults and children. American Journal of Preventive Medicine 2002;23:26–35. [PubMed: 12133735]

Lubans DR, Foster C, Biddle SJH. A review of mediators of behavior in interventions to promote physical activity among children and adolescents. Preventive Medicine. 2008

MacKinnon DP, Fritz MS, Williams J, Lockwood CM. Distribution of the product confidence limits for the indirect effect: Program PRODLIN. Behavior Research Methods 2007;39:384–389. [PubMed: 17958149]

Marcus BH, Bock BC, Pinto BM, Forsyth LH, Roberts MB, Traficante RM. Efficacy of an individualized, motivationally-tailored physical activity intervention. Annals of Behavioral Medicine 1998;20:174–180. [PubMed: 9989324]

Marcus BH, Williams DM, Dubbert PM, Sallis JF, King AC, Yancey AK, et al. Physical activity intervention studies: What we know and what we need to know. A scientific statement from the American Heart Association Council on Nutrition, Physical Activity, and Metabolism 2006;114:2739–2752.

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Marcus BH, Rakowski W, Rossi JS. Assessing motivational readiness and decision -making for exercise. Health Psychology 1992;11:257–261. [PubMed: 1396494]

McAuley E, Jerome GJ, Elavsky S, Marquez DX, Ramsey SN. Predicting long-term maintenance of physical activity in older adults. Preventive Medicine 2003;37:110–118. [PubMed: 12855210]

McAuley E, Morris KS, Motl RW, Hu L, Konopack JF, Elavsky S. Long-term follow-up of physical activity behavior in older adults. Health Psychology 2007;26:375–380. [PubMed: 17500625]

McNeill LH, Wyrwich KW, Brownson RC, Clark EM, Kreuter MW. Individual, social-environmental, and physical environment influences on physical activity among black and white adults: A structural equation analysis. Annals of Behavioral Medicine 2006;31:36–44. [PubMed: 16472037]

Meyerhardt J, Govannucci E, Holmes MD, Chan AT, Chan JA, Colditz JA, et al. Physical activity and survival after colorectal cancer diagnosis. Journal of Clinical Oncology 2006;24:3527–3534. [PubMed: 16822844]

Miller YD, Trost SG, Brown WJ. Mediators of physical activity behavior change among women with young children. American Journal of Preventive Medicine 2002;23:98–103. [PubMed: 12133744]

Montoye, HJ.; Kemper, HCG.; Saris, WHM.; Washburn, RA. Measuring Physical Activity and Energy Expenditure. Champaign, IL: Human Kinetics; 1996.

Muthén, L.; Muthén, BO. MPlus Program. Muthen & Muthen; 2006.

Napolitano MA, Papandonatos GD, Lewis BA, Whiteley JA, Williams DA, King JA, et al. Mediators of physical activity behavior change: A multivariate approach. Health Psychology 2008;27:409–418. [PubMed: 18642998]

Pinto BM, Lynn H, Marcus BH, DePue J, Goldstein MG. Physician-based activity counseling: Intervention effects on mediators of motivational readiness for physical activity. Annals of Behavioral Medicine 2001;23:2–10. [PubMed: 11302351]

Prochaska JO, Velicer WF. The transtheoretical model of health behavior change. American Journal of Health Promotion 1997;12:38–48. [PubMed: 10170434]

Rhodes RE, Plotnikoff RC. Understanding action control: Predicting physical activity intention-behavior profiles across 6 months in a Canadian sample. Health Psychology 2006;25:292–299. [PubMed: 16719600]

Rothman, AJ.; Baldwin, AS.; Hertel, AW. Self-regulation and behavior change: Disentangling behavioral initiation and behavioral maintenance. In: Baumeister, R.; Vohs, K., editors. Handbook of self-regulation: Research, theory, and application. New York, NY: Guilford; 2004. p. 130-148.

Rovniak LS, Anderson ES, Winett RA, Stephens RS. Social-cognitive determinants of physical activity in young adults: A prospective structural equation analysis. Annals of Behavioral Medicine 2002;24:149–156. [PubMed: 12054320]

Saelens BE, Gehrman CA, Sallis JF, Calfas KJ, Sarkin JA, Caparosa S. Use of self-management strategies in a 2-year cognitive-behavioral intervention to promote physical activity. Behavior Therapy 2000;31:365–379.

Sallis JF, Calfas KJ, Alcaraz JE, Gehrman C, Johnson MF. Potential mediators of change in a physical activity promotion course for university students: Project GRAD. Annals of Behavioral Medicine 1999;21(2):149–158. [PubMed: 10499136]

Salmon J, Owen N, Crawford B, Bauman A, Sallis JF. Physical activity and sedentary behavior: A population-based study of barriers, enjoyment, and preference. Health Psychology 2003;22:178–188. [PubMed: 12683738]

Stigglebout M, Hopman-Rock M, Crone M, Lechner L, van Mechelen W. Predicting older adults' maintenance in exercise participation using an integrated social psychological model. Health Education Research 2006;21:1–14. [PubMed: 15980075]

U.S. Department of Health and Human Services. 2nd ed.Washington, DC: US Government Printing Office; 2000. Healthy People 2010: Understanding and improving health.

Velicer WF, DiClemente CC, Prochaska JO, Brandenburg N. A decisional balance measure for assessing and predicting smoking status. Journal of Personality and Social Psychology 1985;48:1279–1289. [PubMed: 3998990]

Weinstein ND. Misleading tests of health behavior theories. Annals of Behavioral Medicine 2007;33:1–10. [PubMed: 17291165]

NIH-PA Author Manuscript

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NIH-PA Author Manuscript

West, SG.; Aiken, LS. Toward understanding individual effects in multicomponent prevention programs: Design and analysis strategies. In: Bryant, KJ.; Windel, M.; West, SG., editors. The science of prevention: Methodological advances from alcohol and substance abuse research. Washington, DC: American Psychological Association; 1997. p. 167-209.

Willet, JB.; Singer, JD. Applied longitudinal data analysis. New York, NY: Oxford University Press; 2003.

Wilson DK. Commentary for Health Psychology special issue: Theoretical advances in diet and physical activity interventions. Health Psychology 2008;27:S1–S2. [PubMed: 18248100]

Wu W, West SG, Taylor AB. Evaluating model fit for growth curve models: Integration of fit indices from SEM and MLM frameworks. Psychological Methods 2009;14:183–201. [PubMed: 19719357]

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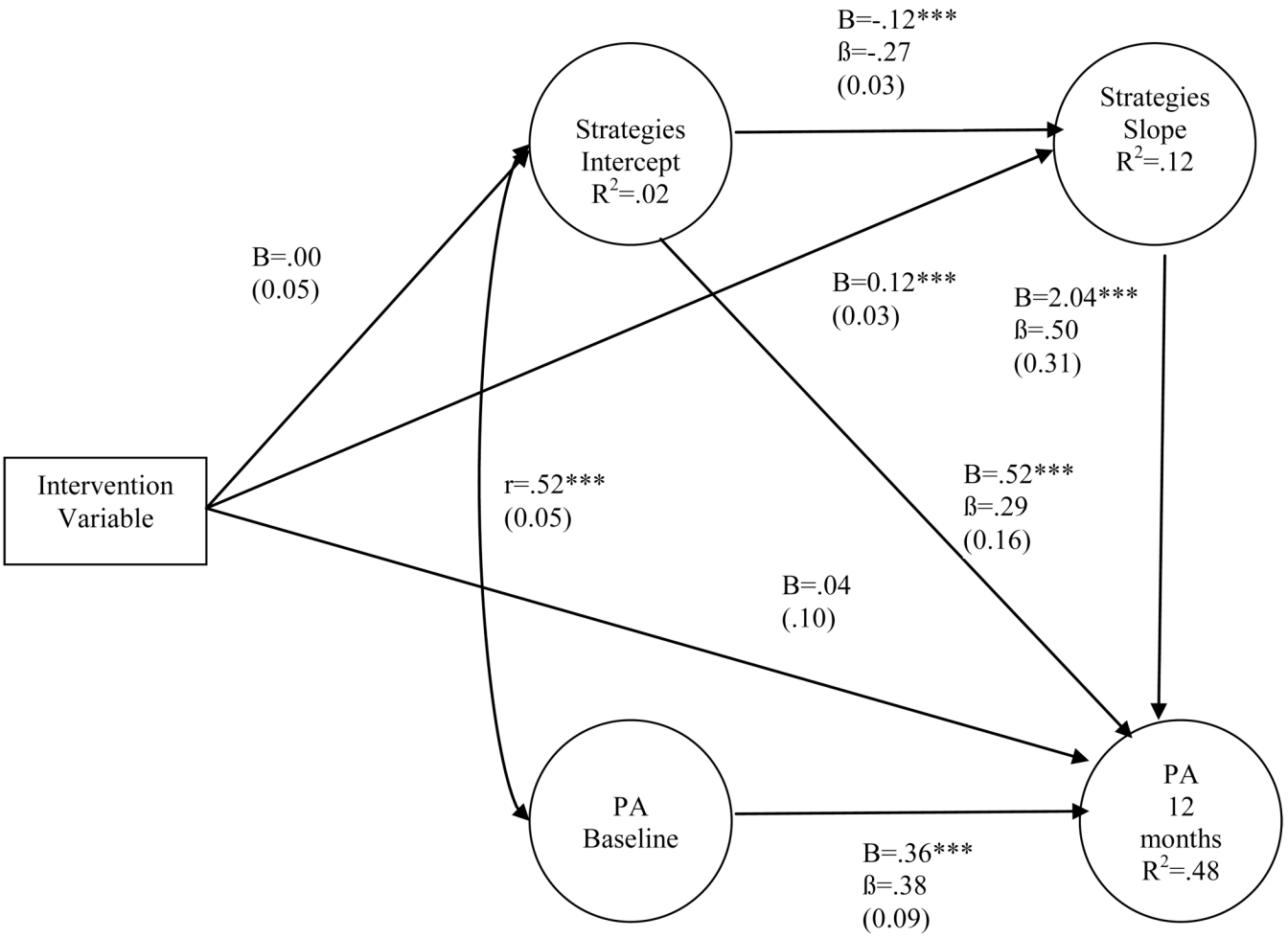

Figure 1.

Mediation model with strategies as the psychosocial mediator. The standard error term for each parameter is presented in parentheses. Observed variables, error terms, and structural paths from gender, age, and education to each growth curve factor and PA at 12-month follow-up were omitted from this figure for presentation purposes.

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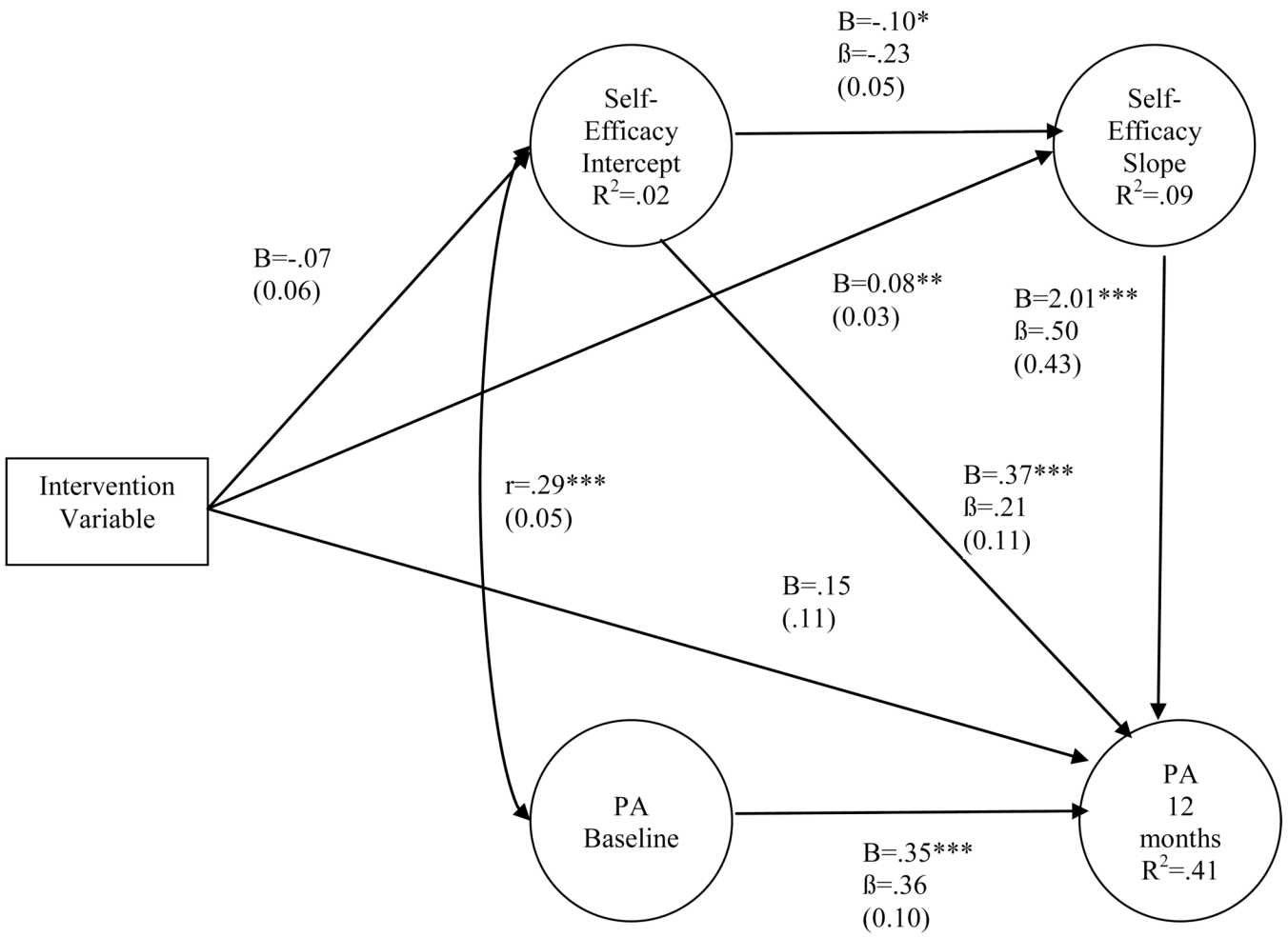

Figure 2.

Mediation model with self-efficacy as the psychosocial mediator. The standard error term for each parameter is presented in parentheses. Observed variables, error terms, and structural paths from gender, age, and education to each growth curve factor and PA at 12-month follow-up were omitted from this figure for presentation purposes.

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Table 1

Descriptive StatisticsMeans (SD) for Study Variables at each Time-Point by Intervention and Control Groups

Variable	Time Point					
	Baseline		*6 months*		*12 months*	
	Intervention	**Control**	**Intervention**	**Control**	**Intervention**	**Control**
Strategies	2.59(0.70)	2.61(0.75)	3.01(0.72)	2.78(0.79)	2.99(0.71)	2.76(0.77)
Pros	4.11(0.66)	4.18(0.65)	4.01(0.70)	4.08(0.70)	3.83(0.75)	4.03(0.72)
Cons	2.11(0.74)	2.15(0.73)	2.13(0.71)	2.13(0.79)	2.03(0.38)	2.10(0.76)
Self-efficacy	2.45(0.82)	2.53(0.79)	2.50(0.91)	2.41(0.91)	2.45(0.84)	2.39(0.83)
Support	2.23(1.06)	2.39(1.09)	2.38(1.08)	2.23(1.07)	2.24(1.02)	2.25(1.08)
Log walking	2.33(1.15)	2.36(1.12)	2.69(0.94)	2.54(1.03)	2.64(1.00)	2.44(1.12)
Log leisure time	1.99(1.33)	2.00(1.36)	2.35(1.21)	2.29(1.29)	2.32(1.27)	2.04(1.40)

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Table 2

Model Fit and Growth Trajectory (Slope) for the Unconditional Growth Models

	Overall Model Fit			
Variable	**χ^2(df)**	**CFI**	**SRMR**	**Linear Growth Slope**
Strategies	30.06(4)***	.953	.041	0.12
Pros	4.52(4)	.999	.012	0.02
Cons	3.96(4)	1.00	.011	0.04
Self-efficacy	4.69(4)	.999	.012	−0.15
Support	3.99(4)	1.00	.005	−0.17

Note. All slope values are unstandardized. CFI=Comparative Fit Index; SRMR= Standardized Root Mean-Square Residual.

* p < .05;

** p < .01;

*** p < .001

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Table 3

Model Fit and Regression Coefficients for Growth Models Predicting (a) Intervention Effects on Psychosocial Trajectories and (b) Physical Activity at 12 months with Psychosocial Trajectories

	Overall Model Fit				
Variable	**χ^2(df)**	**CFI**	**SRMR**	***B***	**β**
a. *Models Predicting Intervention Effects*					
strategies	54.36(5)***	.936	.034	0.12***	
pros	4.96(5)	1.00	.011	− 0.02	
cons	3.72(5)	1.00	.010	0.01	
self-efficacy	9.36(5)	.992	.015	0.09***	
support	7.12(5)	.997	.002	0.04	
b. *Models Predicting PA at 12-Month Follow-Up with the Psychosocial Growth Trajectories*					
strategies	136.77(19)***	.918	.048	2.35***	.52
pros	101.66(19)***	.918	.035	0.05	.01
cons	112.72(19)***	.912	.043	−2.08	−.28
self-efficacy	110.57(19)***	.918	.045	1.91***	.49
support	90.50(19)***	.934	.031	2.05*	.58

Note. *B* represents the unstandardized regression coefficient. CFI=Comparative Fit Index; SRMR=Standardized Root Mean-Square Residual.

* p < .05,

** p < .01,

*** p < .001