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Self-regulation of Exercise Behavior in the TIGER Study

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Abstract

Objective—To test experiential and behavioral processes of change as mediators of the prediction of exercise behavior by two self-regulation traits, self-efficacy and self-motivation, while controlling for exercise enjoyment.

Methods—Structural equation modeling was applied to questionnaire responses obtained from a diverse sample of participants. Objective measures defined adherence (928 of 1279 participants attended 80% or more of sessions) and compliance (867 of 1145 participants exercised 30 minutes or more each session at their prescribed heart rate).

Results—Prediction of attendance by self-efficacy (inversely) and self-motivation was direct and also indirect, mediated through positive relations with the typical use of behavioral change processes. Enjoyment and self-efficacy (inversely) predicted compliance with the exercise prescription.

Conclusions—The results support the usefulness of self-regulatory behavioral processes of the Transtheoretical Model for predicting exercise adherence, but not compliance, extending the supportive evidence for self-regulation beyond self-reports of physical activity used in prior observational studies.

Keywords

African American; Hispanic; heart rate monitoring; mediators; processes of change; self-efficacy; self-motivation; structural equation modeling

Physical activity among US adults is below levels recommended for health promotion [1-3] and is a target of public health intervention [4-6]. Although more than half of US adults say they are active enough to accumulate the amount of physical activity recommended for health (7), less than 10% meet that level when their physical activity is measured objectively by an accelerometer (7,8). A 2-year population-based study found that 30% of adults who

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were sufficiently active in vigorous physical activities failed to maintain that level for six-months [9]. Early clinical trials of exercise typically reported that nearly half the participants dropped out before potentially healthful adaptations could be measured (10,11). Since then, efficacy trials of exercise commonly report adherence (i.e., attendance) rates of 75-85% of the sessions in trials lasting six to 24 months, but they rarely report whether participants who attend also comply with the prescribed intensities and durations of exercise, despite early recommendations that this be done (12) and recent evidence that such compliance predicts health outcomes better than attendance alone (13).

Advances in understanding how to design effective interventions that produce sustainable increases in physical activity, including adherence and compliance, will depend in part upon identifying key mediators (i.e., variables that transmit all or part of the effect of an independent variable on a dependent variable) of change in physical activity [14,15]. The cognitive and behavioral processes of change derived from the Transtheoretical Model of behavior change [16] are putative mediators of change in physical activity [17, 18] that have each been associated with adherence to recommended levels of physical activity [19-21]. The processes have been used to guide the design of more than 20 physical activity interventions [22-25], but the experimental evidence has been mixed as to whether the processes mediate the effects of stage-based interventions to increase physical activity [26-35]. Because the processes are moderately stable across several months in the absence of intervention [21], it is plausible that they might also predict exercise adherence (i.e., attendance at sessions) or compliance (i.e., meeting an exercise prescription during session attendance), especially in conjunction with other variables related to self-regulation of behavior [36].

Self-efficacy and self-motivation offer conceptually distinct explanations of the intensity and persistence of people's exercise behavior, but each involves self-regulation [37]. Self-efficacy is constrained to beliefs about personal ability to overcome barriers to physical activity or otherwise regulate efforts to be active. Although self-efficacy is sensitive to experience in a specific situation, it is influenced by reinforcement history and can develop trait-like qualities to predict a person's tendency to act in related settings [38]. It has usually been measured as a general tendency or trait in studies of exercise adherence [39]. Self-motivation is a generalized, non-specific tendency to persist in the long-term pursuit of behavioral goals independently of context-specific beliefs about reinforcement history, ability, or control [40]. People with high self-efficacy or self-motivation are more likely to develop self-regulation tactics to reach their physical activity goals [41, 42]. Efficacy beliefs can affect physical activity both directly and indirectly by influencing self-regulation (e.g., goal setting, self-persuasion, planning, and problem solving) and perceptions about socio-cultural environments that present barriers or, conversely, provide support for physical activity [42]. People with high self-efficacy tend to set higher goals and strive to achieve them with more effort and persistence than people with low self-efficacy [38]. Similarly, self-motivation includes efficacy beliefs about personal abilities and tendencies to set goals and strive to reach them with effort and persistence [40].

Both self-efficacy and self-motivation have been useful for predicting exercise program adherence [37-40], and research has confirmed that self-regulation processes mediate cross-sectional relations between efficacy beliefs and physical activity participation [43]. However, whether self-efficacy or self-motivation have indirect predictive effects on supervised exercise adherence operating through self-regulation processes has not been reported to our knowledge. The processes of change derived from the Transtheoretical Model (TTM) of stages of change [16, 17] are the most studied self-regulation tactics for physical activity change [22, 25, 44]. We previously found that change in both experiential and behavioral processes, and also their initial levels, predicted self-reports of moderate-to-vigorous physical activity across two years [21]. The usefulness of the processes for predicting physical activity measured objectively as adherence or compliance to a supervised exercise program is not known [18-20, 45, 46].

We report here tests of hypotheses that self-efficacy and self-motivation have: [1] direct effects as predictors of adherence and compliance during a 15-week supervised exercise program and [2] indirect effects, operating through a hypothesized nomothetic network of cognitive and behavioral processes of change, consistent with self-regulation theories [17, 38]. We controlled for exercise enjoyment to test the effects of self-regulation independently of intrinsic motivation [47]. A recent review of mediated effects of self-regulation processes on physical activity change noted the need for direct measures of physical activity rather than reliance only on self-reports [25]. Here, adherence was defined directly by meeting a criterion of session attendance, while compliance was defined by meeting a criterion of the prescribed amount of exercise during the attended sessions based on heart rate monitoring. Meeting these criteria was associated with several health outcomes (e.g., lower blood pressure, blood glucose, cholesterol, and body fat) in the study cohort, as reported elsewhere [13].

Methods

The Training Interventions and Genetics of Exercise Response (TIGER) Study is a prospective cohort study with the goals of introducing sedentary college-aged adults to regular exercise and identifying genetic factors that influence physiological responses to exercise training and exercise adherence [48]. Here we report on five cohorts enrolled at the University of Houston during academic years 2004-2008. Exclusion criteria included having a physical contraindication to aerobic exercise (e.g., cardiomyopathy), a metabolic condition that may alter body composition, and/or pregnancy. All participants provided written informed consent, and the study protocol was approved by the Institutional Review Boards at University of Houston (UH), Baylor College of Medicine, and the University of Texas Health Science Center at Houston. There was no compensation for participation other than academic credit. Participants were 505 men and 774 women who ranged in age from 18-35 years (21.3 ± 3 years), had a body mass index (BMI) of 26.3 ± 6.2, percent body fat of 27.3 ± 9.5%), and came from diverse racial/ethnic groups, mostly non-Hispanic white (28.5%), African American (27.3%), Hispanic (23.7%), and Asian (7.4%).

Procedures

To meet contemporary guidelines for vigorous activity (3), prescribed aerobic exercise training included three 30-minute exercise sessions/week at 65%-85% of age- and gender-predicted maximum heart rate reserve (HRR) for 15 weeks using the subject's choice of treadmill, elliptical trainer, stair stepper, or exercise bike, which was documented at each session. During each exercise session, participants wore validated portable heart rate monitors (Polar Electro, Lake Success, NY). The monitors gave audible feedback when participants were outside their individual training heart rate zone and recorded minute-to-minute heart rate, date, time, and duration for each exercise session.

Data from the heart rate monitors for each participant were downloaded into the manufacturer's software program (E-Series, Polar Electro, Lake Success, NY) and merged with attendance files to formulate a comprehensive database of exercise measures. Participants were required to complete a minimum of 25 minutes within their target heart rate zone for an exercise session to be considered valid.

They completed an average of 29.1 exercise sessions (SD = 6.9) at an average duration of 38.4 (SD = 3.7) min. Average heart rate was 156.6 (SD = 7.9) $b \cdot min^{-1}$ and mean % heart rate reserve (HRR) was 67.9% (SD = 5.8%).

Exercise sessions were held at the UH campus recreation center. Trained staff instructed participants on the use of the exercise equipment and were available on site to check in and out heart rate monitors, answer participant questions, supervise the exercise floor, and to document mode of physical activity; research staff did not provide one-on-one personal training. Participants were instructed to begin recording heart rate upon initiating an exercise session, and monitors were stopped by study staff when the participant completed the session and turned in the monitor. Exercise duration was recorded as the time the monitor was stopped minus the time the monitor was started. Relative exercise intensity was expressed as percent of age-predicted HRR using the average exercise heart rate, as described elsewhere [13]. Approximately 83.2% (27,883/33,473) of the attendance records recorded during the semester had usable heart rate observations. The remaining 16.8% of attendance records had either missing or unusable heart rate data (mainly because of monitor failure), which were then imputed from each participant's mean and standard deviation calculated from available data [13].

Self-report forms were completed by participants in a quiet room on paper teleforms that were individually identified by a bar-code. Once completed, a member of the study staff verified that participants had answered all the questions. After verification of the questionnaire data, the form was scanned into the database using an automated system. Two staff members then independently visually checked the information on the scanner and made corrections as needed. If the entries did not match, the hard copy of the form was visually checked to determine where the error was located, and errors were corrected prior to transfer to the master database.

Exercise adherence—The number of exercise sessions attended was expressed relative to the number of possible sessions each semester per cohort, which varied due to differences in semester length and weather-related university closures: 34, 30, 36, and 37 sessions, respectively for each of the four cohorts. Using a criterion of 80% attendance [13], 928 of

1279 participants (72.6%) were deemed adherent and 351 (27.4%) were defined as non-adherent.

Exercise compliance—A heart rate physical activity score was calculated for each participant to quantify the cumulative volume of exercise (i.e., the duration of exercise sustained at prescribed intensities (a minimum relative exercise intensity of 65% for at least 30 minutes per session) normalized to the number of possible sessions, as described elsewhere [13]. Compliance was defined as an observed score equal to or greater than this prescribed volume (e.g., 65%*30 min/session*34 sessions=663). Non-compliance was defined as an observed score less than this prescribed volume. Using this criterion, 867 of 1145 participants (75.7%) were deemed compliant and 278 (24.3%) were defined as non-compliant.

Measures—Students responded to questions about their gender, age, race/ethnicity, baseline physical activity level, and their marital and employment status at study outset. Self-identified racial/ethnic categories consisted of non-Hispanic White, Hispanic White, African American or Black, Native American or Alaskan, Asian Indian, Asian, or other (e.g., multi-racial).

Body weight was measured to the nearest 0.1 kg using a digital scale (Seca 770, Hanover, MD), and height was measured to the nearest centimeter with a portable stadiometer (Seca Road Rod, Snoqualmie, WA). Quetelet's index (weight in kg/height in m^2) was used to calculate BMI. Percent body fat (%BF) was estimated using dual energy X-ray absorptiometry (DXA) using the manufacturer's recommended procedures (Hologic, Bedford, MA).

Physical activity at study entry was assessed using an ordinal 8-category self-report measure that has been validated using maximal aerobic capacity as the criterion measure [49, 50]. The stability of this measure of physical activity from beginning to end of the semester (ICC-2) was .57.

Processes of Change—Processes of physical activity change were assessed using a self-report measure [19] previously validated for use in the TIGER trial [51]. The measure consists of experiential and behavioral processes conceptualized as two correlated, second-order factors which each consist of first-order constructs (16, 17). Experiential processes include: 1. consciousness raising, (e.g., seeking information); 2. dramatic relief, (e.g., emotional aspects of change); 3. environmental reevaluation, (e.g., assessment of how inactivity affects society); 4. self-reevaluation, (e.g., assessment of personal values); 5. social liberation (e.g., awareness, availability, and acceptance of active lifestyles in society). Behavioral processes consist of: 1. counter conditioning, (e.g., substituting physical activity for sedentary leisure choices); 2. helping relationships, (e.g., using social support during change); 3. reinforcement management, (e.g., self-reward for change); 4. stimulus control, (e.g., managing situations that prompt inactivity or activity). A fifth behavioral process, self-liberation (e.g., commitment and efficacy beliefs about change), could not be identified in the TIGER cohorts [51]. Participants were asked to think of any similar experiences they might be currently having or have had during the past month and to then rate how frequently the event occurs using a 5-point scale: 1 (never), 3 (occasionally), 5 (repeatedly).

Self-efficacy—Confidence to be physically active in the presence of common barriers to being physically active was assessed using a previously published measure [52]. Each item was rated on a 5-point Likert-type scale (1 = strongly disagree to 5 = strongly agree) to the statement, "I am confident I can participate in regular physical activity" when: "I am tired", "I am in a bad mood, "I feel I don't have the time", "I am on vacation", "It is raining, snowing, or *extremely hot*" (italicized condition added for the TIGER study). Acceptable internal consistency reliability of the scale (Cronbach alpha = .76-.78) has been reported for middle-aged adults [52], but to our knowledge the factorial validity of the scale for college students had not been reported prior to this study.

Self-motivation—The original 40-item scale measures a trait-like tendency to persist in the pursuit of goals independently of situational reinforcement [53]. Respondents use a five-point Likert-type scale to rate each item according to the degree they believe it describes them (1 = very unlike me to 5 = very much like me). A 10-item, single factor version of the scale was used that had good fit in prior samples of male (χ^2 = 121.82, df = 35, RMSEA = 0.061 [90% CI = 0.049 - 0.073], CFI = 0.981) and female (χ^2 = 83.69, df = 35, RMSEA = 0.046 [90% CI = 0.033 - 0.058], CFI = 0.986) students from the University of Houston, with acceptable internal consistency (Cronbach alpha = .83) (unpublished observations).

Enjoyment—Questions from the interest/enjoyment scale of the Intrinsic Motivation Inventory [54] were adapted to physical activity as recommended [55]. The 8-item measure asked participants to endorse the following items using a Likert-type scale ranging from 1-7 (1= not at all true; 4= somewhat true; 7= very true): "I enjoy participating in physical activities very much", "physical activities are fun to do", "physical activities do not hold my attention at all", "I would describe physical activities as very interesting", "I think physical activities are quite enjoyable", "while participating in physical activities, I think about how much I enjoy physical activities", "I think physical activities are boring", "I am satisfied with my performance at physical activities".

Analysis

Confirmatory Factor Analysis

The factorial validity and measurement invariance/equivalence of the processes of change scales for use in the TIGER study have been reported previously [51]. Confirmatory factor analysis (CFA) models for measures of self-efficacy, self-motivation, and enjoyment were tested with a maximum likelihood estimator that is robust to non-normality (MLR) and full-information estimation of missing data using M*plus* 7.0 software [56,57]. Covariance coverage exceeded 78% for all variables [57]. Factor models were adjusted for nesting effects of students within semester cohorts by correcting the standard errors of the parameter estimates for between-semester variance using the Huber-White sandwich estimator [56].

Model fit—The comparative fit index (CFI), root mean square error of approximation (RMSEA), and the chi-square (χ^2) statistic were used to evaluate and compare model fit

[58-60]. Values of the CFI around 0.90 were considered acceptable while values ≥ 0.95 indicated good fit. Values of the RMSEA ≤ 0.06 and ≤0.08 reflected close and acceptable fit of the model. The 90% confidence interval (CI) for the RMSEA is also presented. Although factors such as the number of indicators and non-normal distributions affect statistical power, the available sample size was adequate for model tests in the overall sample and for sub-group analyses according to condition [61]. Internal consistency reliability of each scale was estimated by composite reliability based on CFA [58].

Measurement equivalence/invariance—Factor invariance for the self-efficacy, self-motivation, and enjoyment scales was examined by testing and comparing a series of nested models using standard procedures to constrain parameters to be equal across groups [62]. Each successive model (models 1 to 5) included previous model restrictions (i.e. model 3 included restrictions from model 2) plus additional constraints, resulting in a series of nested models. Model 1 freely estimated all hypothesized parameters. Model 2 restricted paths from the factor(s) to the observed items (factor loadings). Model 3 tested equal factor variances and covariances. Model 4 constrained item intercepts (means) to be equal. Model 5 constrained the item uniquenesses (errors) to be equal across groups. The most constrained, equivalent model is reported in the tables. Item errors reflect random variance or systematic variance otherwise not explained by the factor model. Testing the equivalence of item means and errors is very restrictive, and equivalence of factor structure (configural invariance) and loadings (metric invariance) is conventionally considered sufficient criteria for concluding factorial invariance across groups [62].

Nested models were compared based on χ^2 difference tests adjusted by MLR scaling, $\Delta\chi^2$ (df), changes in the value of the CFI (ΔCFI ≤ .01) (63), and overlap in the RMSEA point estimates and 90% CIs between two nested models (62). Differences in the RMSEA and CFI have been found to be superior to interpretations based strictly on χ^2 difference tests which are usually significant [60]. The main criteria used to judge significant model differences were changes in CFI (ΔCFI > .01) and χ^2 difference ($P<.05$) between nested models [63].

Factor models—The factor validity of each scale was examined first by fitting the hypothesized model to the baseline data from a random holdout sample of 500 students using CFA [64]. If the hypothesized model was not supported, modification indices, cross-loadings of items on other factors, covariances between items, standardized residuals, and squared multiple correlations were examined to determine whether misfit was a function of a problem item or the hypothesized factor structure. The revised model was then tested in the full sample. After establishing a good fitting model, multi-group factor invariance was examined. The primary analyses involved testing the factor invariance across males (n=505) and females (n=789) and between African American (n=363), Hispanic (n=300), and Non-Hispanic White (n=368) students. Sample sizes were too small (e.g., < 200) to estimate stable parameters for other racial groups [58, 65]. Secondary analyses were conducted to determine whether the instruments were invariant across age groups (< 20 (n=529), ≥20-21 (n=391) and ≥22-35 (n=356) years), BMI categories (<25 (n=649), 25-29 (n=376), ≥30 N=249), employment status (yes (n=729) or no (n=550) of full time students, weekly baseline physical activity level at entry (≤ 30-60 minutes of vigorous exercise (n=1062) vs.

≥ 1-3+ hours of vigorous exercise (n=205) on the physical activity category scale) [50], and between those who met the attendance or exercise prescription criteria for adherence or compliance) and those who did not. The age groups correspond roughly to comparison of 1st year, 2nd through 4th year, and non-traditional or graduate students. The BMI groups correspond to CDC standards for normal weight, overweight, and obese classifications among adults. Longitudinal invariance was also tested using the same procedure of nested models for participants who provided scores at trial entry and at the end of the first semester for self-efficacy (N=1083), self-motivation (N=1110), and enjoyment (N=870).

Logistic Regression Analysis

Logistic analysis was conducted by full information maximum likelihood estimation using M*plus* 7.0 to first determine univariate predictors of adherence or compliance modeled as categorical variables and, subsequently, to examine prediction models for self-efficacy, self-motivation, enjoyment and the cognitive and behavioral processes after adjustment for any significant covariates.

Structural Equation Modeling

A structural covariance model with robust weighted least squares mean- and variance-adjusted (WLSMV) estimation using M*plus* 7.0 tested the hypothesized relations among self-efficacy, self-motivation, the processes of change, and enjoyment with adherence or compliance during the 15-week exercise program. The model tested included fully standardized paths (i.e., γs) between the exogenous, correlated variables of self-efficacy, self-motivation, and enjoyment and fully standardized paths (i.e., βs) between the endogenous correlated, mediating experiential and behavioral processes of change and the endogenous binary outcome variable of adherence/dropout or compliance/non-compliance modeled as categorical variables. Percent fat was the only covariate that predicted compliance, so it was included in the final model. Critical z-scores (standardized parameter estimate/SE) were used to test significance. Direct and indirect effects were tested using probit analysis, and standard errors were adjusted for nesting effects between cohorts using the Huber-White sandwich estimator [56].

Tests of equivalence of the structural model and the path coefficients between gender, race/ethnicity (African American, Hispanic, non-Hispanic White) and employment groups were based on a change in the CFI and RMSEA (ΔCFI ≤ .01 ΔRMSEA ≤ .01) between a baseline model in which those parameters were freely estimated in each group and a nested model in which these parameters were constrained to be equal between the groups [62].

Results

Confirmatory Factor Analysis

Self-efficacy—The hypothesized model of a single factor was non-positive definite and had poor fit to the data (X^2 (5) = 158.6, CFI = 0.917, RMSEA = 0.156 (95% CI, 0.136-0.178). Modification indices revealed that item 4 (“I am confident I can participate in regular physical activity when I am on vacation”) should be removed because of a low R^2 and high residual variance. The re-specified model had good fit (χ^2 (2) = 10.6, CFI = 0.992, RMSEA = 0.059 [90% CI = 0.027 - 0.095]). Factor loadings ranged from .64 to .81. The nested multi-group invariance tests indicated configural (i.e., factor structure) equivalence. Item errors were equivalent for all grouping variables other than race and baseline physical activity level (which showed equivalent factor variance) and gender (which showed equivalent factor loadings) (see Table 1).

Nested longitudinal invariance tests indicated configural equivalence (χ 71.3 (15), CFI = 0.973, RMSEA = 0.59 (95% CI, 0.046-0.073) and uniqueness (i.e., item errors) invariance across the semester and between adherents and dropouts across the semester (χ^2 difference, $p > .05$ and Δ CFI $\leq .01$). Composite reliability was .84 and .81 at the beginning and end of the semester, respectively. Stability across the semester was .58 (95% CI, .48, .68).

Self-motivation—The hypothesized model of a single factor had acceptable fit to the data (X^2 (35) = 258.9, CFI = 0.943, RMSEA = 0.071 (95% CI, 0.063-0.079). Factor loadings ranged from .61 to .73. The nested multi-group invariance tests indicated that factor structure was equivalent across all groups. Item means and errors were invariant between groups for race, employment, and adherence/dropout status. Factor loadings and factor variance were invariant between gender, age, and baseline physical activity level groupings. Factor loadings were invariant between BMI groups (see Table 1).

Nested longitudinal invariance tests indicated configural equivalence (χ2 (159) = 654.0, CFI = 0.946, RMSEA = 0.056 (95% CI, 0.051-0.060) and metric invariance) across the semester and between adherents and dropouts across the semester (χ^2 difference, p> .05 and Δ CFI $\leq$ .01). Composite reliability was .92 and .89 at the beginning and end of the semester, respectively. Stability across the semester was .49 (95% CI, .35, .62).

Enjoyment—The hypothesized model of a single factor was non-positive definite and had inadequate fit to the data (X^2 (20) = 214.0, CFI = 0.904, RMSEA = 0.098 (95% CI, 0.087-0.110). Modification indices revealed that item 1 (“I enjoy participating in physical activities very much”) and item 3 (“physical activities do not hold my attention at all”) should be removed. Item 1 had high covariances with several other items, and item 3 had a low R^2 (.249) and a high covariance with item 7. The re-specified model had good fit (χ^2 (9) = 16.8, CFI = 0.995, RMSEA = 0.029 [90% CI = 0.000 - 0.051]). Factor loadings ranged from .60 to .96. The nested multi-group invariance tests indicated that factor structure was equivalent across all groups. Item means and errors were invariant between employment, and adherence/dropout groups. Factor loadings and factor variance were invariant between age and BMI groups. Factor loadings were invariant between gender, race, and baseline physical activity level groupings (see Table 1).

Nested longitudinal invariance tests indicated configural equivalence of factor structure (χ2 (47) = 138.5, CFI = 0.979, RMSEA = 0.047 (95% CI, 0.038-0.057) and invariant factor loadings and factor variance across the semester and between adherents and dropouts across the semester (χ^2 difference, p> .05 and Δ CFI $\leq .01$). Composite reliability was .91 and .90 at the beginning and end of the semester, respectively. Stability across the semester was .77 (95% CI, .74, .80).

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Logistic Regression

In bivariate models, odds of adherence were 84% higher per unit elevation in the use of behavioral processes, 3.4% higher per unit elevation in enjoyment, and 54% higher among Hispanic students compared with White. See Table 2. Odds of compliance to the exercise prescription were 1% higher per unit elevation in percent body fat and 40% higher in females compared to males.

Structural Equation Model

The models shown in figures 1 and 2 had acceptable fit to the data for adherence, χ^2 (1011) = 1505.3 (CFI=0.946, RMSEA=0.020, 95% CI=0.017-0.022) and compliance, χ^2 (1052) = 1598.1 (CFI=0.941, RMSEA=0.021, 95% CI=0.019-0.023). Item loadings ranged from .66 to .74 for self-efficacy, .51 to .77 for self-motivation, .54 to .89 for enjoyment, and .52 to .90 (1^{st} order factors) and .52 to .92 (2^{nd} order factors) for the processes of change, consistent with our prior validity study [50]. The prediction of adherence by self-efficacy at program outset was direct (β = -0.281 SE = 0.120, p = .019) and indirect (β = 0.072 SE = 0.032, p = .023), mediated through its positive relation with behavioral change processes (β = 0.527 SE = 0.010, p < .001) which had a positive relation with adherence (β = 0.136 SE = 0.061, p = .025). Self-motivation also had a positive direct relation with adherence (β = 0.041 SE = 0.012, p = .001) and an indirect effect (β = 0.021 SE = 0.009, p = .023) mediated through its positive relation with behavioral processes (β = 0.152 SE = 0.019, p < .001). Adherence was positively related to enjoyment (β = 0.185 SE = 0.078, p = .017) but was unrelated to age, baseline physical activity, and percent body fat (p-values ≥ .388). The probability of adherence was 13%, 24%, and 22% higher for a standard deviation elevation in self-motivation, behavioral processes, and enjoyment respectively, but 38% lower for a standard deviation elevation in self-efficacy.

The prediction of compliance by self-efficacy was direct (β = -0.082 SE = 0.018, p < .001). Self-motivation had no effects on compliance (p-values ≥.706). Enjoyment was positively related to compliance (β = 0.055 SE = 0.025, p = .025). Compliance was positively related to percent body fat (β = 0.071 SE = 0.015, p < .001) measured at the beginning of the trial. For a standard deviation elevation, the probability of compliance was 23% higher for enjoyment and 27% lower for self-efficacy.

Invariance tests between the structural model and a nested model that constrained path coefficients among the latent variables and with adherence or compliance to be equal (Δ CFI < .01, Δ RMSEA ≤ .001 χ^2 difference, p > .03) indicated that the model had acceptable, equivalent fit across groups according to gender and race/ethnicity groups (African American, Hispanic, non-Hispanic White) for both adherence and compliance).

Discussion

The results support the usefulness of behavioral processes of change derived from the Transtheoretical Model [16, 17] for predicting adherence during a 15-week exercise program of vigorous physical activity but not compliance with the prescribed amount of physical activity at each exercise session. Only enjoyment of physical activity measured at the outset of the trial was directly related to both attendance and compliance. The types, intensity and duration of exercise provided an exercise exposure consistent with the current Physical Activity Guidelines for Americans [3] and were associated with clinically meaningful health outcomes reported elsewhere for these cohorts [13]. The results support a hypothesized nomothetic network of behavioral change processes as mediators of the predictive relationship between self-efficacy and self-motivation, which are theorized to operate in part through the use of self-regulation tactics.

Self-efficacy, self-motivation, enjoyment and both the experiential and behavioral processes were positively related to contemporary, self-reported physical activity levels measured at the beginning of the trial. However, only the behavioral processes, self-motivation, and enjoyment of physical activity had a positive, prospective relationship with adherence to the exercise program in the multivariate structural model. In contrast with theory, self-efficacy had inverse direct relations with both adherence and compliance. Similar to our findings here, several trials based on TTM theory reported that the behavioral processes mediated increases in self-reported physical activity (26, 27, 34, 35) or fitness (35), while self-efficacy was unrelated to physical activity change. However, those studies used various measures of self-efficacy without confirming their measurement properties in the groups sampled. It is to be expected that the item content of a general measure of self-efficacy for physical activity will influence the extent to which the measure predicts exercise adherence or compliance (38, 39). Prior studies also relied on univariate tests of mediation, which do not rule out confounded or redundant influences (35) nor estimate indirect effects that can be important for advancing theory and for improving clinical practice.

The TTM postulates that people preferentially use behavioral processes while they maintain an exercise program. The present results suggest that people who say they are already using such processes are also more likely to adhere to a new exercise program. The lack of an association between the use of experiential processes has been reported in trials that measured physical activity by self-report [26, 27, 34, 35] and is consistent with TTM theory, which holds that experiential processes are most important for forming the intent to become physically active. Observational studies of community adults have reported that both cognitive and behavioral processes were related to maintenance of moderate [66] or vigorous [67] physical activity. However, adherence in those studies was determined using self-reports of action and maintenance stages, which have modest agreement with maintenance of regular moderate or vigorous physical activity sufficient for public health [68].

Self-efficacy and self-motivation were positively related to both experiential and behavioral processes, consistent with the hypothesized roles of the processes as self-regulatory tactics. Although related to self-efficacy, self-motivation had additional influences on adherence, consistent with its conceptual origins as an independent predictor of exercise adherence [40]. Because people are likely to vary in their use of specific change processes across time, our results suggest that the general measure of behavioral processes provides a modest but reliable prediction of adherence to an exercise program. The predictive value of the structural model was independent of higher adherence rates among females, Hispanic students and students having higher percent body fat at trial entry. Other putative influences

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on adherence including age, employment status, and physical activity at trial entry were not predictive of adherence or compliance in these cohorts of college students.

The direct, inverse association of self-efficacy with adherence, despite self-efficacy's positive relations with the behavioral change processes and self-motivation, indicates suppression (i.e., inconsistent mediation) of the relation between self-efficacy and adherence. This suppression effect indicates that some participants with low self-efficacy at program entry were adherent regardless of past activity history and their use of the behavioral processes. Conversely, other participants having initially high self-efficacy used behavioral processes but also used experiential processes that were unrelated to adherence, suggesting that they overestimated their regulatory efficacy to overcome barriers to adherence. Alternatively, other factors not in the model (e.g., genetic variation, physical activity outside the supervised exercise program after entry into the trial, or environmental factors such as social support, access to other physical activity opportunities, or other barriers) might also have moderated the observed relations.

These results provide longitudinal evidence using an objective measure of exercise adherence to support earlier cross-sectional results [19, 20] and longitudinal evidence in a population-based cohort of adults [21]. Here, college students of varying ages who reported using behavioral processes during the month preceding entry into the TIGER trial were more likely to adhere, regardless of their enjoyment of exercise. This association was observed independently of gender, race/ethnicity, employment status, percent body fat and physical activity assessed by self-report at trial entry. There was no manipulation of the transtheoretical constructs nor control of changing circumstances that can influence people's choices to be physically active. Nonetheless, the findings show that participants who said they had been using behavioral processes to help regulate their physical activity before they entered the exercise program were more likely to adhere at a level that was clinically meaningful for health in these cohorts [13]. The results encourage further intervention to determine whether adherence, measured directly, can be improved by increasing participants' use of behavioral processes of self-regulation, as has been recommended elsewhere [25].

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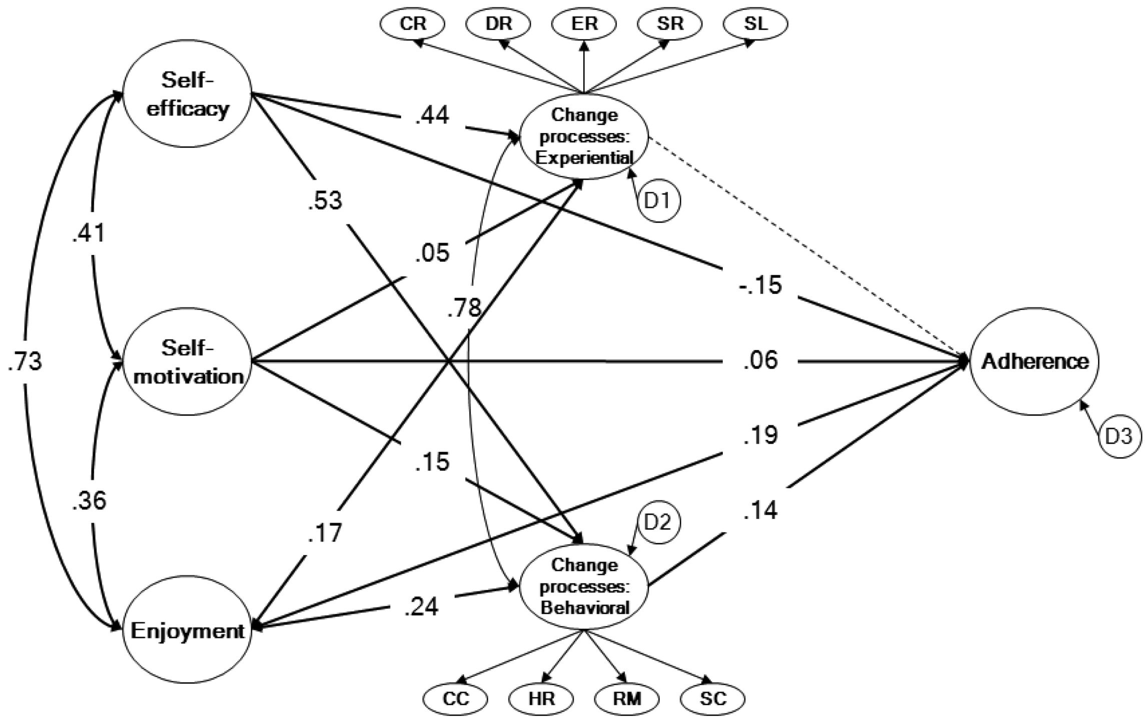

Figure 1.

Structural model predicting exercise adherence by direct and indirect relations of self-efficacy, self-motivation, enjoyment, and transtheoretical self-regulation processes among TIGER participants. Path coefficients (β) are fully standardized. Broken lines indicate non-significant direct effects. First-order processes: CR (consciousness raising), DR (dramatic relief), ER (environmental reevaluation, SR (self-reevaluation), SL (social liberation), CC (counter conditioning), HR (helping relations), RM (reinforcement management), SC (stimulus control).

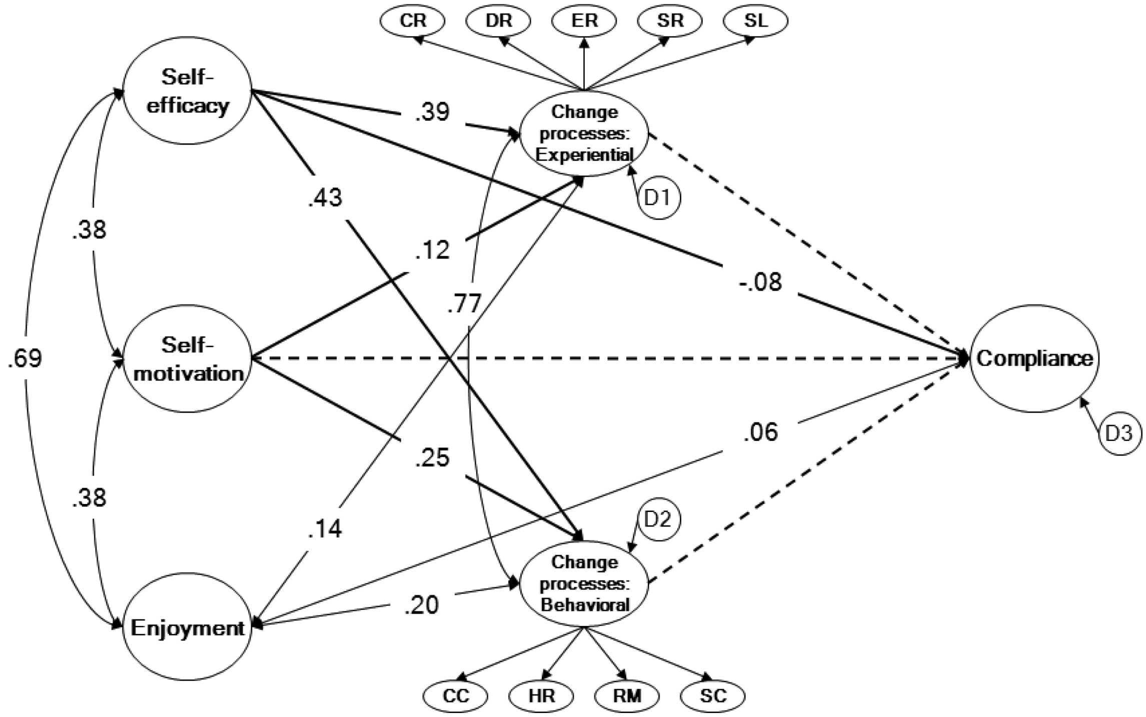

Figure 2.

Structural model predicting exercise compliance by direct and indirect relations of self-efficacy, self-motivation, enjoyment, and transtheoretical self-regulation processes among TIGER participants. Path coefficients (β) are fully standardized. Broken lines indicate non-significant direct effects. First-order processes: CR (consciousness raising), DR (dramatic relief), ER (environmental reevaluation, SR (self-reevaluation), SL (social liberation), CC (counter conditioning), HR (helping relations), RM (reinforcement management), SC (stimulus control). Percent body fat was the only extraneous covariate related to compliance. ($\beta = 0.07$, $p < .001$)

Table 1

Model fit and measurement equivalence- invariance between groups according to student characteristics.

	Self-efficacy				Self-motivation				Enjoyment			
	Model	χ^2 (df)	CFI	RMSEA (90% CI)	Model	χ^2 (df)	CFI	RMSEA (90% CI)	Model	χ^2 (df)	CFI	RMSEA (90% CI)
Gender	1	15.1 (4)	0.991	.067 (.033 -.104)	1	298.8 (70)	0.939	.072 (.063 - .080)	1	24.9 (18)	0.995	.028 (.000 - .052)
	2	21.9 (7)	0.987	.058 (.032 -.087)	3	303.9 (80)	0.940	.066 (.058 - .074)	2	31.1 (23)	0.994	.026 (.000 - .048)
Race/Ethnicity)	1	8.1 (6)	0.999	.032 (.000 -.083)	1	286.9 (105)	0.948	.072 (.062 - .082)	1	45.5 (27)	0.989	.051 (.023 - .076)
	3	16.4 (14)	0.998	.023 (.000 - .060)	5	353.6 (165)	0.946	.058 (.050 - .067)	2	71.2 (37)	0.981	.059 (.038 - .080)
Age	1	14.8 (6)	0.992	.059 (.021 - .098)	1	386.3 (105)	0.935	.074 (.071 - .088)	1	53.5 (27)	0.991	.054 (.032 - .075)
	5	41.4 (30)	0.990	.030 (.000 - .051)	3	410.1 (125)	0.934	.073 (.065 - .081)	3	72.0 (39)	0.989	.050 (.032 - .068)
BMI	1	14.6 (6)	0.993	.059 (.020 - .098)	1	322.9 (105)	0.940	.070 (.061 - .079)	1	42.1 (27)	0.992	.041 (.012 - .064)
	5	49.2 (30)	0.983	.039 (.017 - .058)	2	378.7 (123)*	0.930	.070 (.062 - .078)	3	62.2 (39)	0.987	.042 (.021 - .061)
Employment	1	10.3 (4)	0.995	.050 (.012 - .089)	1	242.4 (70)	0.944	.062 (.054 - .071)	1	32.9 (18)	0.993	.041 (.017 - .062)
	5	17.6 (16)	0.999	.013 (.000 - .040)	5	262.0 (100)	0.947	.050 (.043 - .058)	5	50.9 (36)	0.993	.029 (.000 - .046)
Physical activity	1	14.7 (4)	0.991	.066 (.032 - .103)	1	271.1 (70)	0.948	.068 (.059 - .076)	1	29.3 (18)	0.994	.036 (.006 - .058)
	3	20.9 (8)	0.989	.051 (.025 - .078)	3	299.2 (80)*	0.943	.066 (.058 - .074)	2	44.1 (23)*	0.989	.043 (.023 - .062)
Adherence	1	18.4 (4)	0.990	.076 (.043 - .112)	1	304.2 (70)	0.937	.072 (.064 - .081)	1	27.6 (18)	0.995	.033 (.000 - .056)
	5	21.7 (15)	0.996	.024 (.000 - .047)	5	334.8 (100)	0.936	0.061 (.054 - .068)	5	50.8 (36)	0.992	0.029 (.000 - .046)
Compliance	1	16.8 (4)	0.988	.072 (.039 - .109)	1	300.1 (70)	0.945	.072 (.064 - .081)	1	28.7 (18)	0.994	.035 (.000 - .057)
	5	16.7 (16)	0.999	.008 (.000 - .038)	5	331.3 (100)	0.945	0.061 (.053 - .068)	5	50.5 (36)	0.992	0.028 (.000 - .046)

χ^2 = chi-square test statistic, df=degrees of freedom, CFI= comparative fit index, RSMEA= root mean square error of approximation, CI=confidence interval. Model 1 is freely estimated, Models 2-5 tested equal: loadings, factor variance/covariance, item means, and item errors, respectively. The most constrained, equivalent model is reported here.

*indicates χ^2 difference test, p-value < .05; all others p-value > .10

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Table 2

Standardized bivariate correlations among the exogenous variables. Factor scores are used for latent variables. Logistic odds ratios for predicting adherence (top) and compliance (bottom) are shown on the first diagonal (cognitive and behavioral processes are modeled as correlated factors). Corresponding correlations based on probit analysis are shown on the second diagonal.

	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Self-efficacy	0.867	−.071*											
	0.945	−.040**											
2. Self-motivation	.340***	1.025	.025*										
		0.959	.008										
3. Experiental processes	.381***	.221***	0.720	−.081									
			0.942	.007									
4. Behavioral processes	.458***	.346***	.833***	1.844*	.060*								
				1.094	.035								
5. Enjoyment	.483***	.327***	.364***	.498***	1.034***	.023***							
					.988	.025*							
6. Physical activity	.379***	.220***	.255***	.506***	.442***	.956	−.053						
						.927	−.088						
7. Percent fat	−.197***	−.160***	.006	−.212***	−.345***	−.395***	1.004	.023					
							1.012***	.067***					
8. Age	.073**	−0.007	.101*	.013	−.027	.008	.109***	.971	−.048				
								1.011	.019				
9. Gender (Female > Male)	−.234***	.043**	.095***	−.134***	−.237***	−.345***	.722***	−.127*	1.236	.079			
									1.403*	.124*			
10. Hispanic vs White	−.084	.086	−.098*	−.144*	.070	−.179**	.190***	−.044	.068	1.540*	.160*		
										1.600	.170		

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	1	2	3	4	5	6	7	8	9	10	11	12	13
11. Black vs White	−.087***	.103***	−.103***	−.255***	−.045	−.273***	.005	−.188***	240***	------	1.033	.025	
											1.005	.004	
12. Employed	.055	.027*	.081***	.089*	.069	.019	−.008	.060***	.025	.023	−.013	1.034	.063
												1.030	.053
13. Training zone minutes	.052***	.004	.063	.029**	.059	.020*	−.026	.013	.008	−.034	−.014	.070	

* p < .05

** p < .01

*** p <.001.