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Using Constructs of the Transtheoretical Model to Predict Classes of Change in Regular Physical Activity: A Multi-Ethnic Longitudinal Cohort Study

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Abstract

Explaining variation in meeting recommended levels of physical activity across time is important for the design of effective public health interventions. To model longitudinal change in constructs of the Transtheoretical Model and test their hypothesized relations with change in meeting the Healthy People 2010 guidelines for regular participation in moderate or vigorous physical activity, a cohort (N=497) from a random, multi-ethnic sample of 700 adults living in Hawaii was assessed at 6-month intervals three or more times for 2 years. Latent class growth modeling was used to classify people according to their initial levels and trajectories of change in the transtheoretical variables and separately according to whether they met the physical activity guideline each time. Relations of the variables and their change with classes of meeting the guideline were then tested using multinomial logistic regression. Despite declines or no change in mean scores for all transtheoretical variables except self-efficacy, participants who maintained or attained the physical activity guideline were more likely to retain higher scores across the 2 years of observation. The usefulness of transtheoretical constructs for predicting maintenance of, or increases in, public health levels of physical activity was generally supported. These longitudinal results support earlier cross-sectional findings which indicate that, contrary to theory, people appear to use both experiential and behavioral processes while they attempt to increase or maintain their physical activity.

Keywords

Asian American; Native Hawaiian/Pacific Islander; Public health recommendation; Latent class growth modeling

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Introduction

Physical activity among US adults is below levels recommended for health promotion [1–4] and is a target of public health intervention [5]. Advances in understanding the effectiveness and sustainability of increased physical activity after intervention 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) and moderators (i.e., extraneous variables that modify that effect) [6] of change in physical activity [7–9]. The processes of change derived from the Transtheoretical Model of behavior change [10] are putative mediators, and possibly moderators, of change in physical activity that have been understudied [11, 12].

The Transtheoretical Model theorizes that people use experiential (i.e., cognitive–affective) and behavioral (i.e., overt tactics) processes to alter their experiences and environment [13, 14] in ways to prompt or support their attempts to move between progressive stages of change from building intention to subsequent adoption and maintenance of regular physical activity. The experiential and behavioral processes are conceptualized as two correlated, second-order factors which each consist of five first-order constructs [14]. 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, 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) self-liberation, e.g., commitment and efficacy beliefs about change; (5) stimulus control, e.g., managing situations that prompt inactivity or activity). Critical reviews of the usefulness of the Transtheoretical Model for designing physical activity interventions [15, 16] have mainly focused on the need to determine whether the original stages are valid for understanding physical activity [17–20]. Much less attention has been paid to whether the processes are valid [21–25] and useful for understanding change in physical activity [11, 26, 27], even though the processes have been used to guide the design of about 20 physical activity interventions [28].

Contrary to theory, the cumulative evidence from cross-sectional comparisons of the processes across physical activity stages suggests that both experiential and behavioral processes are used by people classified as being in either adoption or maintenance stages [21, 29]. A few prospective, observational studies of adults reported mixed evidence that the processes are related to stage progression [30–33]. Experimental evidence has also been mixed as to whether the processes mediate the effects of stage-based interventions to increase physical activity [34–38].

Likewise, evidence for the validity of other transtheoretical constructs has been mainly limited to cross-sectional comparisons across stages [11], rather than showing predictive relations with longitudinal change in physical activity. Based on expectancy theory, decisional balance is a multidimensional set of values perceived as advantages (i.e., pros) and disadvantages (i.e., cons) of behavioral change [39]. Pros typically are higher and cons are lower when post-action stages are compared with pre-action stages [11]. Self-efficacy has typically been defined as a person’s belief in capabilities to overcome personal, social, and environmental barriers to exercising [40]. Generally, cross-sectional analyses have shown that the confidence to overcome barriers to physical activity increases linearly across stages [11]. Conceptually related to barrier self-efficacy, temptations describe urges to engage in a specific habit (e.g., remain sedentary or insufficiently active) in the midst of difficult situations [41]. Construct validity of temptations has also been supported by significantly lower levels of temptations in the later stages [42]. However, our recent findings question whether temptations predict physical activity independently of barriers self-efficacy [43].

Past studies have not used longitudinal designs to determine the stability or variation in transtheoretical constructs across periods of time sufficient to test their usefulness for understanding maintenance of physical activity (e.g., more than 6 months). We report here on naturally occurring change in key transtheoretical variables across 2 years in a multi-ethnic cohort of adults living in Hawaii. We previously showed in the cohort that the stages were not useful for predicting 6-month changes in physical activity defined as meeting the Healthy People 2010 guidelines for regular participation in either moderate or vigorous physical activity [44]. So, in this paper, we were interested to learn whether the other transtheoretical variables, namely, processes of change, pros and cons for participating in physical activity, self-efficacy for overcoming barriers to physical activity, and temptations to remain inactive were useful for predicting whether people met the guideline during the two years of observation. We used a validated measure of physical activity [45] that was feasible for administration by interview in a population-based survey and that provided estimates of weekly time spent in moderate or vigorous physical activity during the past 7 days [45].

In addition to examining cross-sectional relations between the transtheoretical variables and meeting the Healthy People 2010 guideline for regular participation in moderate or vigorous physical activity, we used latent class growth modeling to exploit the longitudinal cohort design to estimate trajectories of change in the transtheoretical variables and to test their hypothesized relations with 6-month changes in meeting the physical activity guideline. The hypothesized relations were generally consistent with theory about correlates of progression between pre-action and post-action stages (see Fig. 1) [46]. For our purposes here, we tested general hypotheses that initial status or change in behavioral processes (presumably, post-action processes) would better predict action and maintenance of physical activity (defined in this study as meeting the Healthy People 2010 physical activity guideline) than would initial status or change in experiential processes (presumably, pre-action processes). We also tested whether increases in self-efficacy and decisional pros, concurrent with decreases in decisional cons and temptations, would predict maintenance or increases in meeting the physical activity guideline at each 6-month assessment, consistent with theory.

Latent class growth modeling has the advantage of determining whether multiple groupings of initial levels and change exist in a cohort. Thus, it is not limited to independent tests of initial status (i.e., baseline levels) and change in the whole cohort, whereby between-person differences are treated as random error rather than as potentially true individual differences. Rather, latent class growth modeling provides an opportunity to determine whether discrete classes of the cohort exist that might have unique relations with classes of change in physical activity that would go otherwise undetected if the entire cohort is evaluated together. For example, people who sustain high expectations of personal benefits of being physically active (i.e., have high decisional pros) from baseline throughout the observation period should have higher odds of meeting the physical activity guideline at all assessments than people with lower or declining expectations.

Methods

Participants

This longitudinal, cohort study used a random sample of 700 adults (18 years or older) living in Hawaii who were assessed every 6 months for 2 years. A cohort of 497 participants completed the measures at least three times and was used for analysis; 468 completed the measures four times and 394 completed them all five times. The cohort did not differ from the total random sample on physical activity or demographics reported elsewhere [44]. Characteristics of the cohort were: 63.6% female; 31.8% Asian; 19.3% Native Hawaiian/ Pacific Islander; 39.8% Caucasian; 8.0% Other (African American, Mexican, Puerto Rican, American Indian, Mixed non-Hawaiian); 52.9% Married; mean age=48.8 years, SD=16.7, range=18–90; mean education=15.0 years, SD=2.9; median income=$40,000 to $50,000)

Procedures

The questionnaire was programmed into a computer assisted telephone interview system by a local survey firm. Prior to survey administration, the questionnaire was pilot tested for interpretability and ease of administration. Participants were recruited using random digit dialing procedures with a maximum of three call attempts per household including at least 1 week and 1 weekend day attempt. A total of 4,392 calls made by random digit dialing resulted in contact, of which 2,785 calls (63.41%) reached eligible households and 1,607 calls reached ineligible households (pagers, non-residents, non-English speakers). A qualified individual whose birthday was closest to the date of the phone call was asked to participate. Trained interviewers informed potential participants that they would receive a $10 incentive per interview, with $25 for the last one, if they agreed to participate in 30-min interviews regarding their physical activity over 2 years. The survey firm recruited 700 participants (a 25.13% recruitment rate= recruited/eligible households). Informed consent ensuring privacy and confidentially was obtained from participants. The University of Hawaii Institutional Review Board approved all procedures.

Measures

Demographics—Participants provided self-reports of gender, age, race/ethnicity, years of education, household income, marital status, height, and weight, which have been described elsewhere [44].

Physical Activity—The International Physical Activity Questionnaire was used to assess physical activity. It has acceptable measurement properties for monitoring population levels of physical activity among 18- to 65-year-old adults in diverse settings. Reliability and criterion validity are comparable to other self-report measures of physical activity [45]. Physical activity is recorded as hours and additional minutes of participation during the past 7 days in activities rated according to multiples of metabolic equivalents (METS) expressed as MET-min per week. It assesses frequency and duration of moderate (four METS) and vigorous (eight METS) physical activity, appropriate for categorization of individuals as meeting public health guidelines for sufficient regular physical activity, defined as moderate physical activity for at least 30 min five or more days per week or vigorous physical activity for at least 20 min three or more days per week [1].

Processes—The Process of Change questionnaire includes 30 statements that participants are asked to rate in terms of frequency of occurrence over the past month [23, 25]. The questionnaire contains three items for each of the ten specific processes of change and provides individual scores (ranging from 1 = Never to 5=Repeatedly) [23]. For this study, alpha coefficients ranged from 0.72 to 0.88 for experiential processes and from 0.76 to 0.85 for the behavioral processes. We reported elsewhere that the hypothesized ten-factor solution for the processes of change was not supported in this cohort [25]. Revised models provided acceptable fit for either 8 correlated factors represented by 18 items from the nine of the original processes (self-reevaluation was not identified) or a two-factor second-order structure of those 8 factors. One factor was comprised of two self-liberation items and two reinforcement management items. However, seven of those factors were under identified by

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just two items each. Another model of five correlated factors provided an acceptable fit and was better identified [25], so it was used in this study. The first process, self-reevaluation/self-liberation/reinforcement management, is represented by the three self-reevaluation items (e.g., “regular exercise will make me a healthier, happier person”; 2 self-liberation items: “I tell myself that I can keep exercising if I try hard enough”, “I believe that I can exercise regularly”; and 2 reinforcement management items: “One of the rewards of regular exercise is that it improves my mood”, “If I engage in regular exercise, I find that I get the benefit of having more energy”. The second process, dramatic relief/environmental reevaluation, is represented by two items from dramatic relief: “I am afraid of the results to my health if I do not exercise”, “I get upset when I realize that people I love would have better health if they exercised”; and the three items from environmental reevaluation: (e.g., “exercising regularly will prevent me from being a burden to the health care system”). Processes 3 to 5 are represented by three item indicators each for consciousness raising (e.g., “I look for information related to exercise”); helping relationships (e.g., “I have someone who encourages me to exercise”); and counter conditioning (e.g., “when I feel tired, I make myself exercise anyway because I know I will feel better afterwards”).

Pros and Cons (Decisional balance)—This two-factor, ten-item scale measures the importance of pros and cons of physical activity using a five-point scale (1 = not important=5 extremely important) [25]. Internal consistencies for this study were 0.83 and 0.71 for pros and cons, respectively.

Self-efficacy—This six-item instrument measures confidence to be physically active in the presence of barriers. Each item is rated on a 5- point scale (1 = not at all confident to 5=completely confident) and represents one of six specific domains: negative affect, excuse making, being active alone, equipment access, resistance from others, and weather [25]. The self-efficacy scale was internally consistent (alpha=0.85) in this study.

Temptations—The two-factor (i.e., affect and competing demands), ten-item temptations scale assesses how tempted an individual is not to be physically active [42]. The items are preceded by the sentence “Using the scale below, please indicate how TEMPTED you are NOT to exercise in the following situations”. The responses were rated on a scale ranging from 0% (not at all tempted) to 100% (extremely tempted). Internal consistencies for this study were 0.87 and 0.91 for affect and competing demands subscales, respectively.

Analysis

Latent Class Growth Modeling—Trajectories of change in each variable were estimated using latent class growth modeling in Mplus 5.1 [47]. Missing data were imputed using full information likelihood estimation, which uses iterative simultaneous equations to estimate missing data by computing a likelihood function for each individual based on all the available data. In contrast to other techniques such as pairwise and listwise deletion of cases, this approach yields accurate fit indices and parameter estimates with up to 25% simulated missing data [48]. The cohort completed 2,328 of 2,485 possible assessments (93.7%); missing scores for the completed assessments were 104 of 6,461 (1.6%). Latent class growth modeling uses structural equation modeling procedures to estimate two latent variables from longitudinal data: (a) one representing the initial status or starting value, and (b) the other representing the trajectory of change across time, which is modeled as a random effect which differs between people [49].

First, we used latent transition analysis to determine participants’ movement between discrete latent classes of meeting or not meeting the *Healthy People 2010* recommendations for participation in regular moderate or vigorous physical activity, which we have described elsewhere [44]. Class 1 mostly met the guideline each time. Class 2 partially met the guideline at baseline and at 6 months and fully met it by months 18 and 24. Class 3 partially met the guideline each time but had reduced rates at months 18 and 24. Class 4 virtually never met the guideline. Next, latent class growth modeling was used to test the trajectories change for these latent classes of physical activity change. The physical activity classes are referred to as Group 1 (always met), Group 2 (not met–to meeting), Group 3 (partially met, declining), and Group 4 (never met) in the multinomial logistic regression analyses for simplicity and to avoid confusion with the latent classes of growth in the trans-theoretical variables.

Latent class growth modeling was also used to test change in participants' perceptions of decisional pros and cons for participating in physical activity, their self-efficacy for overcoming barriers to physical activity, temptations (affect and competing demands) to not exercise, and five processes of change: consciousness raising, self-evaluation/self-liberation, dramatic relief/environmental reevaluation, counter conditioning, and helping relationships. In contrast to repeated measures ANOVA or ordinary least squares regression analysis, latent class growth modeling provides parameter estimates of intra- and inter-individual differences in linear or nonlinear trajectories of change and the relation between change and initial status, as well as providing maximum likelihood techniques for missing data, measures of model fit, and diagnostics for poor fit [47]. A key advantage of latent class growth modeling is the ability to use the initial status and change latent variables as independent or dependent variables in prediction models.

In the current study, the change latent variable was modeled twice—first using just a linear change function and second using both linear and quadratic change functions. Parameters and their standard errors were estimated for initial status (i.e., mean at baseline), change (i.e., slope of differences across the five time points), and the variances (i.e., inter-individual differences) of initial status and change. Critical z scores (parameter estimate/SE) were used to test significance. Tests of differences between classes on initial status and change in the physical activity variables were based on χ^2 difference tests 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. A worsening in model fit of the nested model relative to the baseline indicates that parameters are different between groups.

Model fit was evaluated with multiple indices [50]. The chi-square statistic assessed absolute fit of the model to the data and ideally should be statistically non-significant. However, the test is sensitive to sample size, so other fit indices were also used [51]. Values of the Comparative Fit Index (CFI) and the non-normed Tucker Lewis Index (TLI) ≥ 0.90 and 0.95 were used to indicate acceptable and good fit. Values ≤0.06 of the root mean square error of approximation (RMSEA) and the standardized root mean square residual (SRMR) were used to represent close fit. Values ≥0.96 for CFI in combination with values of the SRMR≤0.08 results in the least sum of type I and type II error rates, especially in sample sizes ≤250 [51]. The number of classes for initial status and change were tested by a significant change in the Vuong–Lo–Mendell–Rubin likelihood ratio test (χ^2 Δ). 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 subgroup analyses [52].

Multinomial Logistic Regression Analysis—Multinomial logistic regression analysis using maximum likelihood estimation was performed in SPSS 17.0 using full information maximum likelihood imputed data to determine the odds that initial baseline values and change in the transtheoretical constructs could accurately predict membership in the classes of meeting or not meeting the physical activity guideline at each 6-month assessment, while adjusting for demographic covariates that were associated with classification accuracy. Physical activity group 4 (never met the guideline) was the reference for all logistic odds-ratios (see Fig. 2). Odds associated with orthogonal linear and quadratic change are reported when applicable. Statistical significance of likelihood ratios and goodness of model fit were tested by χ^2 tests. Strength of association was estimated using the Nagelkerke pseudo R^2.

The following variables were tested as covariates in the logistic models: gender, age (<50≥ years); race (Hawaiian/Pacific Islander vs. White; Asian vs. White; multi-ethnic vs. White); education (<15≥ years); median annual household income (≤$40,000–50,000>); marital status (married or living with partner vs. widowed, separated/divorced, or never married); body mass index (<25≥). All logistic models were adjusted for gender and education, which were the only significant ($p<0.05$) covariates.

Results

Latent Class Growth Models

Physical Activity—A one-class quadratic model had acceptable fit to the data (χ^2 (6)=20.2, p=0.003, CFI=0.986, TLI=0.986, RMSEA= 0.069), but a four-class quadratic model gave the best fit (χ^2 (16)=9.9, p=0.870; likelihood ratio χ^2 Δ(4)=24.9, p< 0.001) for the trajectory of change in meeting or not meeting the Healthy People 2010 guideline for regular participation in either moderate or vigorous physical activity. Likelihood probabilities for membership in the 4 classes (i.e., groups) were: 75%, 83%, 87%, and 80%, respectively. Fig. 2 shows the probabilities of class membership. Nearly all of Group 1 (n=112) were likely to meet the guideline at baseline and through the first year and 88% and 86% were likely to meet it at months 18 and 24. Group 2 (n=95) had 60% of the members meet the guideline at baseline. The rate dropped to 44% at 6 months and then rose to 81% at month 12 and 100% at months 18 and 24. Group 3 (n=171) had rates that remained around 40% through the first year and then dropped to 26% and 35% at months 18 and 24. Only 5–10% of Group 4 (n=119) were likely to ever meet the guideline.

TTM Constructs—Single-class, quadratic models provided the best fit for the trajectory of change in Consciousness raising, Helping relationships, and Counter conditioning (χ^2 (6)<9.2, p ≥ 0.161, CFI>0.99, TLI>0.99, RMSEA≤0.033, SRMR≤0.022; see Table 1). Each variable decreased linearly from the baseline through 12 months and then increased to 24 months but remained below the baseline levels. Only the linear change in Consciousness raising was related to initial status at baseline (r −0.269, p=0.042). Single-class linear models gave the best fit for change in decisional cons (χ^2 (10)=23.1, p=0.010, CFI=0.970, TLI>0.970, RMSEA= 0.051, SRMR=0.039); self-efficacy (χ^2 (10)=9.9, p=0.453, CFI>1.0, TLI>1.0, RMSEA=0.000, SRMR=0.051); and both temptations scales (χ^2 (10)<32.6, p<0.002, CFI> 0.940, TLI>0.940, RMSEA≤0.068, SRMR≤0.054). Decisional cons and temptations-affect decreased across 24 months, while self-efficacy increased and temptations-competing demands did not change. Change was unrelated to initial status for all variables.

One-class change models had good fit for self-reevaluation/self-liberation/reinforcement management and dramatic relief/environmental reevaluation (χ^2 (6)≤8.3, p≥0.216, CFI>0.99, TLI>0.99, RMSEA≤0.028, SRMR≤0.035) and had acceptable fit for decisional pros (χ^2 (10)= 45.5, p<0.001, CFI=0.966, TLI>0.966, RMSEA=0.085, SRMR=0.081). However, two-class quadratic change models provided the best fit for self-reevaluation/self-liberation/reinforcement management (χ^2 Δ(14)=421.9, p<0.001); dramatic relief/environmental reevaluation (χ^2 Δ(15)= 97.6, p<0.001); and decisional pros (χ^2 Δ(11)=421.1, p<0.001) See Table 1. For self-reevaluation/self-liberation/reinforcement management, Class 2 had a higher mean at baseline [χ^2 diff=189.13, *df*=1, $p<0.001$], a larger linear decline [χ^2 diff=8.16, *df*=1, $p=0.004$], and a larger quadratic increase [χ^2 diff=6.08, *df*=1, $p=0.014$] compared to Class 1 (see Fig. 3). Initial status was related ($p<0.001$) to linear change ($r=-0.70$) and quadratic change ($r=0.67$) in Class 1 but not Class 2 ($p>0.455$). For dramatic relief/environmental reevaluation, Class 2 had a lower mean at baseline [χ^2 diff=530.67, *df*=1, $p<$ 0.001], a larger linear decline [χ^2 diff=6.49, *df*=1, $p=0.01$], and a quadratic increase [χ^2 diff=15.67, *df*=1, $p<0.001$] compared to Class 1 which had only a linear decline (see Fig. 3). Initial status was related to linear change ($r=-0.61$, $p=0.015$) in Class 1 but not Class 2 ($p>0.637$). A two-class linear model gave the best fit for decisional Pros. Class 2 had a higher mean at baseline than Class 1 [χ^2 diff=187.98, *df*=1, $p<0.001$], but the linear decline was the same in each class [χ^2 diff=0.225, *df*=1, $p=0.635$] (see Fig. 3). Change was unrelated to initial status in each group ($p>0.408$).

Multinomial Logistic Regression Analysis: One-Class Change Models of Transtheoretical Variables

The logistic models for all variables were significant (linear models: χ^2 (12)=36.1 to 144.1, $p<0.001$; linear and quadratic models: χ^2 (15)=42.2 to 174.7, $p<0.001$) and had acceptable fit (χ^2 (1,233 to 1,473) = 1,238.0 to 1,485.1, $p=0.243$ to 0.598; $R^2=0.08$ to 0.32). Results are presented in Table 2. Physical activity group 4 (never met the guideline) was the reference for all logistic odds-ratios.

Consciousness Raising—A unit elevation in initial level was 53%, 38%, and 20% more likely in the always met, not met-to-meeting and partially met, declining groups, respectively. A unit linear decline was 14% less likely in the always met group and 11% less likely in the not met-to-meeting group. The odds of a unit quadratic increase were 5% higher in the always met group (scores returned to the level of the baseline after the initial decline through month 12). Odds of declining scores in the partially meeting class did not differ from the never met group.

Helping Relationships—Initial levels were not different from the never met physical activity group in the always met or the partially met, declining groups, but odds of a unit elevation were 17% higher in the not met-to-meeting group. A unit linear decline was 4% less in the always met group, but odds of linear declines in the other physical activity groups did not differ. Quadratic changes did not differ among the groups.

Counter Conditioning—A unit elevation in initial level was twice as likely in the always met physical activity group and was 80% and 33% more likely in the not met-to-meeting and partially met, declining groups, respectively. A unit linear decline was 15%, 14%, and 7% less likely in those groups. Odds of a unit quadratic increase were 9%, 8%, and 4% more likely in the always met, not met-to-meeting, and partially met, declining groups, respectively (scores increased to near baseline levels after the initial decline through month 12).

Decisional Cons—A unit elevation in initial level was 11% less likely in the always met group, but initial levels and odds of declining scores did not differ among the physical activity groups.

Self-Efficacy—Odds of a unit elevation in initial level were 37%, 24%, and 14% higher in the always met, not met-to-meeting, and partially met, declining physical activity groups. A unit increase was 8% more likely in the always met group and 5% more likely in the not met-to-meeting groups. Odds of change in the partially met, declining group were not different from the never met group.

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Temptations (Affect)—A unit elevation was 3% lower in the always met group, and a unit decline was 1% more likely in the always met and not met-to-meeting groups. Otherwise, initial levels and change did not differ between physical activity groups.

Temptations (Competing Demands)—A unit elevation was 3%, 2%, and 1% less likely in the always met, not met-to-meeting, and partially met, declining groups, respectively. A unit increase was 1% less likely in all physical activity groups compared to the never met group.

Multinomial Logistic Regression Analysis: Two-Class Change Models of Transtheoretical Variables

The logistic models for all variables were significant (linear models: χ^2 (12)=27.5 to 56.5, p<0.008; linear and quadratic models: χ^2 (15)=37.6 to 58.3, p<0.001) and had acceptable fit (χ^2 (327 to 1128)=302.0 to 1144.9, p=0.293 to 0.471; R^2=0.10 to 0.26). Results are presented in Table 3.

Self-reevaluation/Self-Liberation/Reinforcement Management—In the model for process class 1, a unit elevation was 21%, 25%, and 10% more likely in the always met, not met-to-meeting, and partially met, declining physical activity groups, respectively. A unit linear decline was 5% less likely and a unit quadratic increase was about 5% more likely in both the always met (scores increased above the baseline level at month 12) and not met-to-meeting groups (scores returned to near baseline levels after an initial decline through month 12). In the model for process class 2, the odds of a unit elevation of initial level were 45% and 37% higher and odds of a unit quadratic increase were 7% and 8% lower in the always met and not met-to-meeting physical activity groups (there were no linear declines in the groups, but scores in the never met group returned to the baseline level after a decline from months 6 through 18).

Dramatic Relief/Environmental Reevaluation—In the model for process class 1, initial levels and change were not associated with group differences in meeting the guideline. In the model for process class 2, a unit elevation in initial level was 10% more likely and a unit linear decrease was 5% less likely in the always met physical activity group.

Decisional Pros—In the model for process class 1, a unit elevation in initial level was 16% more likely in the always met group and 13% more likely in the not met-to-meeting group. A unit linear decline was about 5% less likely in the always met and the partially met, declining physical activity groups. In the model for process class 2, odds of a unit elevation in initial level were 40%, 18%, and 15% higher in the always met, not met-to-meeting, and the partially met, declining physical activity groups, respectively. A unit linear decline was 10% and 6% less likely in the always met and not met-to-meeting groups.

Discussion

To our knowledge, we provide here the first longitudinal evidence from a population base that supports the usefulness of constructs of the Transtheoretical Model [10] for predicting maintenance or increases of physical activity at levels judged to be sufficient for public health promotion. However, results were only partly consistent with hypothesized influences of the decisional balance and process of change variables.

A decrease in counter conditioning was less likely in groups who maintained, attained, or partially met the physical activity guideline when each group was compared with participants who never met the guideline, consistent with the hypothesized importance of counter conditioning as a post-action behavioral process. A decrease in helping relationships, another behavioral process, was less likely only in the group that maintained physical activity at or above the guideline. A decrease in consciousness raising, a presumably pre-action, experiential process, was less likely in groups who maintained or attained the guideline, but not in the partially met, declining group. These results provide longitudinal evidence to support earlier cross-sectional evidence [21, 29] indicating that, contrary to original transtheoretical theory derived from psychotherapy and smoking cessation [13, 14], people appear to use both experiential and behavioral processes while they attempt to increase or maintain their physical activity.

Consistent with theory, high initial levels and increases in self-efficacy observed every 6 months for two years were more likely among participants who always met the guideline and among those who did not initially meet the guideline but subsequently met it during the last year of observation. Likewise, a decrease in temptations-affect was more likely and an increase in temptations-competing demands was less likely in people who maintained, attained, or partially met the physical activity guideline.

In contrast, neither initial levels nor change in decisional cons were associated with whether people met the physical activity guideline. A decrease in decisional pros was less likely in groups meeting the guideline, especially those who maintained or attained the guideline. Pros did not consistently differ between people who partially met the guideline and those who never met the guideline as would be predicted by transtheoretical theory.

Novel features of the study were the use of a prospective cohort design to observe patterns of naturally occurring, 6-month changes across 2 years in transtheoretical constructs and a test of their relations with maintenance or change in physical activity levels defined according to patterns of meeting or not meeting the Healthy People 2010 guidelines for regular participation in moderate or vigorous physical activity [1]. The associations were observed despite no manipulation of the transtheoretical constructs and no control for circumstances that can also change to influence people’s choices to be physically active. Thus, the influence of the cognitive and experiential processes might be stronger in experimental settings designed to manipulate the processes of change while controlling other personal and environmental influences on physical activity [28]. The use of a self-report measure of physical activity recalled during the past week, without random time sampling or objective verification, is a weakness of the study. Nonetheless, the serial measures strengthen the reliability of the observed associations, although they may be inflated by common method artifact. Accurate surveillance of changes in free-living physical activity in a population base remains a measurement conundrum.

Because of yet-to-be-resolved measurement issues regarding the processes, we were unable to conduct strong tests of stimulus control and reinforcement management, two important behavioral processes. Also, based on our previous factor analyses [25], we used a process that combined self-reevaluation, which is an experiential process, with items from self-liberation and reinforcement management, which are each behavioral processes. This hybrid process declined less in people who maintained or attained the guideline, again suggesting that both experiential and behavioral processes are important for maintenance of high physical activity levels. However, this was observed only in change class 1 (about 45% of the cohort) that had lower initial scores and less linear decline in the process. Another experiential process, dramatic relief/environmental reevaluation, was less likely to decline only in the those who maintained physical activity at or above the guideline, and this was observed only in change class 2 that had lower initial scores and greater change in the process (about 75% of the cohort). The factor validity of the original change processes hypothesized for physical activity has received very little study, despite popularity of the Transtheoretical Model in physical activity research [11, 12, 28]. Given the inconsistent evidence for the structure of the existing scales used to measure the processes, we recommend renewed attempts to develop contemporary item content that may better indicate the conceptual basis of the hypothesized factors as they apply to physical activity behavior change generally or in specific populations or settings [53].

Notwithstanding the unresolved measurement issues, our findings provide initial evidence from a 2-year prospective study that naturally occurring change in several trans-theoretical constructs is useful for predicting transitions between meeting and not meeting a guideline for sufficient participation in health-promoting physical activity. This longitudinal evidence, not previously available from an ethnically diverse population cohort, provides empirical support for the theoretical role of select transtheoretical constructs as correlates of change in physical activity and warrants further experimental tests of their putative roles as mediators of change in physical activity among adults. Because the focus of our investigation was on meeting the Healthy People 2010 guideline for regular participation in either moderate or vigorous physical activity, our results do not address the usefulness of transtheoretical constructs for the prediction of early stage adoption when sedentary people build the intention to engage in regular physical activity. Our results also do not apply to walking, which is measured separately from moderate physical activity by the IPAQ without regard to pace. Easy or slow walking would be moderately intense only for elderly or people with disability or very low fitness [54]. The current Physical Activity Guidelines for Americans recommends 150 min of moderate physical activity or 75 min of vigorous physical activity, or suitable combinations [4], but the scientific advisory committee for those guidelines acknowledged that lower amounts of physical activity will likely be important for public health [55]. Further research efforts like this one are needed to determine the utility of the Transtheoretical Model for explaining longitudinal transitions between sedentary and active habits at lower levels of physical activity than we evaluated here.

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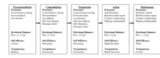

Fig. 1.
Hypothesized changes in TTM constructs of processes of change, decisional balance, self-efficacy, and temptations according to stages (adapted [46])

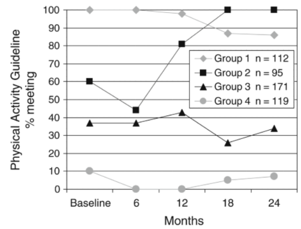

Fig. 2.

Latent class growth modeling of meeting the Healthy People 2010 guideline for regular participation in moderate or vigorous physical activity. Group 1 (always met), Group 2 (not met-to meeting), Group 3 (partially met, declining), Group 4 (never met). Probabilities of group membership are shown as % meeting

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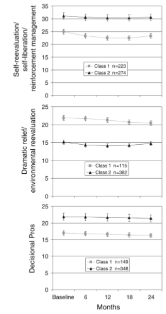

Fig. 3.

Latent class growth modeling of processes of change. Tests of linear and quadratic change are presented in Table 1

Table 1

Baseline means (scores are summed across items) and change for the latent class growth models of transtheoretical variables

	Model	*N*	Baseline mean (SE) variance (SE)	Linear change (SE) variance (SE)	Standardized linear change	Quadratic change (SE) variance (SE)	Standardized quadratic change
Consciousness raising	Single class	497	7.53 (0.140)***	−0.571 (0.10)***	−0.53	0.12 (0.023)***	0.60
			6.94 (0.76)***	1.17 (0.48)**		0.04 (0.03)	
Self-reevaluation/self-liberation/reinforcement management	Class 1	223	24.92 (0.51)***	−2.01 (0.44)***	0.40	0.40 (0.10)***	0.41
			41.68 (4.50)***	25.23 (4.83)***		0.97 (0.28)***	
	Class 2	274	31.07 (0.39)***	−0.62 (0.23)**	−0.49	0.12 (0.05)*	0.56
			7.34 (1.52)***	1.59 (1.41)		0.05 (0.07)	
Dramatic relief/environmental reevaluation	Class 1	115	21.69 (0.44)***	−0.22 (0.36)	−0.16	−0.05 (0.08)	0.00
			3.85 (1.69)*	1.90 (1.41)		0.00 (0.08)	
	Class 2	382	15.29 (0.28)***	−0.88 (0.21)***	−0.73	0.20 (0.05)***	0.72
			9.31 (2.46)***	1.43 (1.64)		0.08 (0.08)	
Helping relationships	Single class	497	7.61 (0.15)***	−0.53 (0.12)***	−0.51	0.11 (0.03)***	0.60
			6.29 (0.96)***	1.09 (0.68)		0.04 (0.04)	
Counter conditioning	Single Class	497	9.08 (0.14)***	−0.37 (0.12)***	−0.34	0.08 (0.03)**	0.27
			5.38 (0.84)***	1.19 (0.64)*		0.09 (0.03)**	
Decisional Pros	Class 1	149	16.96 (0.49)***	−0.19 (0.17)	−0.33		
			8.53 (3.33)**	0.33 (0.38)			
	Class 2	348	21.88 (0.28)***	−0.12 (0.06)*	−0.36		
			4.46 (0.88)***	0.11 (0.07)			
Decisional Cons	Single class	497	6.75 (0.13)***	−0.18 (0.04)***	−0.71		
			5.25 (0.58)***	0.06 (0.06)			
Self-efficacy	Single class	497	19.18 (0.24)***	0.16 (0.06)**	0.31		
			21.31 (1.96)***	0.26 (0.14)*			
Temptations (affect)	Single class	497	37.42 (1.02)***	−2.62 (0.37)***	−0.58		

	Model	*N*	Baseline mean (SE) variance (SE)	Linear change (SE) variance (SE)	Standardized linear change	Quadratic change (SE) variance (SE)	Standardized quadratic change
			165.54 (38.01)***	20.46 (5.54)***			
Temptations (competing demands)	Single class	497	44.85 (1.07)***	0.34 (0.42)	0.06		
			156.89 (43.26)***	28.40 (6.94)***			

***$p<0.001$,

**$p<0.01$,

*$p<0.05$

Table 2

Multinomial logistic regression analysis using single-class models of change in transtheoretical variables to predict classes (i.e., groups) of meeting or not meeting the Healthy People 2010 guideline for physical activity. Group 4 (never met) is the reference for all models

	Single class	Odds ratio	95% CI	*p* value
Consciousness raising				
Group 1 Always met	Initial status	1.529	1.355–1.726	<0.001
	Linear change	0.864	0.818–0.913	<0.001
	Quadratic change	1.049	1.000–1.096	0.033
Group 2 Not met to met	Initial status	1.375	1.217–1.553	<0.001
	Linear change	0.887	0.839–0.938	<0.001
	Quadratic change	1.041	0.996–1.087	0.078
Group 3 Partially met	Initial status	1.203	1.081–1.338	0.001
	Linear change	0.983	0.936–1.032	0.495
	Quadratic change	1.015	0.977–1.056	0.436
Helping relationships				
Group 1 Always met	Initial status	1.065	0.963–1.178	0.218
	Linear change	0.961	0.924–0.999	0.045
	Quadratic change	1.020	0.985–1.057	0.264
Group 2 Not met to met	Initial status	1.167	1.053–1.294	0.003
	Linear change	0.967	0.929–1.007	0.103
	Quadratic change	1.026	0.989–1.063	0.174
Group 3 Partially met	Initial status	1.057	0.966–1.156	0.231
	Linear change	0.979	0.946–1.015	0.256
	Quadratic change	1.011	0.979–1.044	0.505
Counter conditioning				
Group 1 Always met	Initial status	1.997	1.726–2.312	<0.001
	Linear change	0.850	0.804–0.898	<0.001
	Quadratic change	1.090	1.048–1.143	<0.001
Group 2 Not met to met	Initial status	1.801	1.560–2.079	<0.001
	Linear change	0.855	0.809–0.903	<0.001
	Quadratic change	1.076	1.032–1.124	0.001
Group 3 Partially met	Initial status	1.325	1.186–1.479	<0.001
	Linear change	0.933	0.894–0.974	0.001
	Quadratic change	1.036	1.002–1.073	0.040
Decisional Cons				
Group 1 Always met	Initial status	0.892	0.797–1.000	0.049
	Linear change	0.976	0.935–1.019	0.266
Group 2 Not met to met	Initial status	0.997	0.896–1.110	0.959
	Linear change	0.998	0.957–1.040	0.917
Group 3 Partially met	Initial status	0.991	0.903–1.088	0.852
	Linear change	1.012	0.976–1.049	0.533
Self-efficacy				

	Single class	Odds ratio	95% CI	*p* value
Group 1 Always met	Initial status	1.373	1.280–1.473	<0.001
	Linear change	1.076	1.045–1.107	<0.001
Group 2 Not met to met	Initial status	1.239	1.161–1.323	<0.001
	Linear change	1.050	1.022–1.079	<0.001
Group 3 Partially met	Initial status	1.139	1.081–1.201	<0.001
	Linear change	1.017	0.995–1.040	0.132
Temptations (affect)				
Group 1 Always met	Initial status	0.973	0.960–0.986	<0.001
	Linear change	1.011	1.006–1.015	<0.001
Group 2 Not met to met	Initial status	0.990	0.976–1.003	0.121
	Linear change	1.007	1.003–1.012	0.002
Group 3 Partially met	Initial status	0.996	0.985–1.008	0.519
	Linear change	1.003	0.999–1.007	0.107
Temptations (competing demands)				
Group 1 Always met	Initial status	0.966	0.954–0.978	<0.001
	Linear change	0.990	0.986–0.994	<0.001
Group 2 Not met to met	Initial status	0.980	0.968–0.992	0.001
	Linear change	0.989	0.985–0.993	<0.001
Group 3 Partially met	Initial status	0.987	0.977–0.997	0.011
	Linear change	0.995	0.992–0.998	0.003

Table 3

Multinomial logistic regression analysis using two-class models of change in transtheoretical variables to predict classes (i.e., groups) of meeting or not meeting the Healthy People 2010 guideline for physical activity. Group 4 (never met) is the reference for all models

	Class 1				Class 2			
		OR	95% CI	*p* value		OR	95% CI	*p* value
Self-reevaluation/self-liberation/reinforcement management								
Group 1 Always met	Initial status	1.206	1.082–1.344	0.001	Initial status	1.450	1.233–1.705	<0.001
	Linear change	0.949	0.916–0.983	0.004	Linear change	1.046	0.986–1.110	0.138
	Quadratic change	1.063	1.029–1.099	<0.001	Quadratic change	0.932	0.888–0.977	0.004
Group 2 Not met to met	Initial status	1.250	1.127–1.386	<0.001	Initial status	1.374	1.160–1.626	<0.001
	Linear change	0.951	0.921–0.980	0.001	Linear change	1.042	0.979–1.109	0.199
	Quadratic change	1.047	1.018–1.076	0.001	Quadratic change	0.915	0.870–0.963	0.001
Group 3 Partially met	Initial status	1.096	1.020–1.178	0.012	Initial status	1.138	0.984–1.317	0.081
	Linear change	0.983	0.961–1.007	0.170	Linear change	0.993	0.940–1.048	0.799
	Quadratic change	1.012	0.992–1.034	0.236	Quadratic change	0.961	0.919–1.005	0.083
Dramatic relief/environmental reevaluation								
Group 1 Always met	Initial status	1.006	0.723–1.399	0.972	Initial status	1.101	1.010–1.200	0.028
	Linear change	0.882	0.769–1.012	0.074	Linear change	0.949	0.918–0.981	0.002
					Quadratic change	0.974	0.944–1.006	0.107
Group 2 Not met to met	Initial status	1.128	0.817–1.555	0.464	Initial status	1.014	0.929–1.108	0.753
	Linear change	0.946	0.826–1.083	0.423	Linear change	0.985	0.952–1.018	0.371
					Quadratic change	0.980	0.949–1.012	0.214
Group 3 Partially met	Initial status	0.979	0.717–1.336	0.892	Initial status	1.017	0.947–1.093	0.637
	Linear change	0.917	0.804–1.046	0.197	Linear change	0.978	0.951–1.006	0.124
					Quadratic change	1.010	0.983–1.037	0.480
Decisional Pros								
Group 1 Always met	Initial status	1.157	1.032–1.298	0.013	Initial status	1.403	1.219–1.616	<0.001
	Linear change	0.956	0.917–0.997	0.036	Linear change	0.905	0.861–0.951	<0.001
Group 2 Not met to met	Initial status	1.129	1.006–1.267	0.039	Initial status	1.180	1.029–1.352	0.017
	Linear change	0.965	0.928–1.003	0.074	Linear change	0.943	0.897–0.990	0.018
Group 3 Partially met	Initial status	1.095	0.994–1.207	0.065	Initial status	1.146	1.019–1.289	0.023
	Linear change	0.951	0.917–0.984	0.004	Linear change	0.972	0.931–1.014	0.186