

# Differential Use of Strategic Constructs of the Transtheoretical Model across Accelerometer-determined Sedentary Time

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**Objectives:** In this study, we investigated the differences in strategic constructs of the Transtheoretical Model (TTM) across accelerometer-determined sedentary time. **Methods:** A total of 201 college students participated in a TTM questionnaire for sedentary behavior and wore an accelerometer for 7 consecutive days to assess sedentary time. Multivariate analyses of variances (MANOVA) with *post hoc* pairwise comparisons were conducted to determine mean differences in the strategic constructs across quintiles of sedentary time. Tests for linear trends were conducted using orthogonal polynomial coefficients. **Results:** Compared with participants in higher quintiles of sitting time, 8 out of 10 processes of change (eg, mostly consciousness raising [ $\eta^2_p = .09$ ]) were used significantly more frequently by those in the lowest quintile ( $p < .05$ ) with negative linear trends ( $p_{\text{trend}} < .05$ ). We found no statistically significant differences in the constructs of self-efficacy and decisional balance across the quintiles. **Conclusions:** Based on this preliminary analysis it appears that several intervention methods such as awareness raising, incentivization, self-motivation, and social norm building would be more beneficial to reduce sitting time or to protect their current sitting time from relapse.

**Key words:** processes of change; physical activity; sitting

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Despite evidence supporting the deleterious role of prolonged sedentary behaviors on all-cause mortality and cardiovascular disease mortality, children and adults in the United States (US) spend 55% of their waking time being sedentary (ie, approximately 7.7 hours per day).<sup>1</sup> Considerable attention has been focused on reducing sedentary time as an important public health strategy to prevent premature mortality. To reduce sedentary behavior, researchers have designed several types of interventions such as counseling-based,<sup>2,3</sup> Web-based,<sup>4</sup> and activity monitor-based.<sup>5</sup> However, the design and evaluation of sedentary

behavior focused interventions remains at an early stage of development, especially in building theory-based approaches for addressing sedentary behavior and health outcomes. Thus, there is a compelling need for research to clarify the theory-based promising strategies to develop the relevant interventions for reducing sedentary behavior.<sup>6</sup>

Empirical evidence from prior research suggests that interventions based on theoretical foundations are more effective in health behavior change as compared with those lacking theoretical concepts.<sup>7</sup> The Transtheoretical Model (TTM) is a theoretical framework designed to assess an individual's in-

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tentional readiness to change a behavior (eg, stages of change) and to provide relevant strategies to change the behavior through a series of stages (eg, processes of change, self-efficacy, and decisional balance).<sup>8</sup> This model has been applied to various health and health risk behaviors such as smoking,<sup>9</sup> alcohol use,<sup>10</sup> substance abuse,<sup>11</sup> and physical activity.<sup>12</sup> However, most studies applying the TTM to their targeted behavior interventions have solely used the central organizing construct, stages of change, and neglected the strategic constructs of the model (ie, processes of change, self-efficacy, and decisional balance) in spite of the fact that they potentially provide important insight into the content of behavior change interventions.<sup>13</sup> According to a meta-analytic review examining the effectiveness of TTM-based interventions on physical activity improvement, the effectiveness of interventions are moderated by the strategic constructs, particularly self-efficacy and processes of change.<sup>14</sup>

As the demand for development of theory-based intervention to reduce sedentary behavior has increased, the TTM, including all core constructs was developed and validated for sedentary behavior.<sup>15,16</sup> Han et al<sup>15</sup> examined the differential use of the strategic constructs across stages in a sample of adults (aged 18 to 24 years) attending a 4-year university. They found that some processes of changes (ie, consciousness raising, environmental reevaluation, counter condition, self-liberation, and stimulus control) and other constructs (ie, self-efficacy and decisional balance) were more frequently involved in overcoming the barriers to stage progression in later stages compared to those in earlier stages, supporting the importance of relevant strategy use in accordance with individual's readiness of change.

Whereas substantial attention has been given to the TTM, it has received simultaneous exceptional criticism, especially on the accuracy of stage classification.<sup>17,18</sup> For example, although stage classification primarily relies on the duration of individual's readiness of change (eg, changing a behavior within the next 30 days or 6 months), the cut-points differentiating between the stages may be arbitrary and not temporally defined. For example, an individual who is planning to change a behavior within the next 30 days may be classified into a different stage from another individual planning to change his/her behavior in 31 days. The practical limitation of the stage classification (ie, assessing the 'readiness'

of change instead of actual values) can worsen the effectiveness of the TTM for changing a behavior. Identifying the additional relationships between objective values for a specific behavior and the strategic constructs of the TTM is warranted. Thus, the purpose of the current study was to investigate the differential use of the strategic constructs of the TTM across accelerometer-determined sedentary time.

## METHODS

### Participants and Protocol

The targeted population for this study was college students, age 18-24 years, from various academic disciplines at a large urban university in the southern US. The sample used for this study was selected to maintain continuity with previous study investigating TTM for sedentary behavior.<sup>15</sup> Participants were recruited using e-mail advertisements, flyers, and word-of-mouth within the university. Because the intentional focus of the current study was on sedentary behavior of college students, exclusion criteria included those who were out of the age range of 18 to 24 years or had any impairments that could preclude normal daily activities. Overall, 225 college students voluntarily participated in the study, and 24 participants were excluded from the data analyses due to not meeting the minimum valid wear time criteria including dropout (N = 8).<sup>19,20</sup> All participants (104 men and 97 women) were provided and signed a written informed consent prior to any data collection. After informed consent, participants received a tri-axial accelerometer (ActiGraph GT3X+; Pensacola, FL) and written instructions for proper wear. Participants were asked to wear the activity monitor on their right hip during all waking hours for 7 consecutive days to assess sedentary time. On the day of device return, participants participated in a package of questionnaires including questions collecting demographic information and previously developed TTM questionnaire for sedentary behavior.<sup>15</sup>

### Instruments

**Accelerometer-determined sedentary time.** Raw data were sampled over the 7-day observation period. Once the accelerometers were returned by participants, data were downloaded and reintegrated to a one-second epoch using ActiLife6 software,

**Table 1**  
**Descriptions of Processes of Change**

Constructs	Description	Item Example
<i><b>Cognitive Processes</b></i>		
<b>Consciousness Raising</b>	Increasing information about self and sedentary behavior	I think about information from articles and advertisements on how to decrease sedentary time
<b>Dramatic Relief</b>	Experiencing emotional feelings about one's sedentary behavior	I worry that sedentary behaviors can be harmful to my body
<b>Environmental Reevaluation</b>	Assessing how one's sedentary behavior affects physical environment	I wonder how my sedentary lifestyle affects those people who are close to me
<b>Self-reevaluation</b>	Assessing how one feels and thinks about oneself in response to sedentary behavior	I feel more competent myself when I decide to avoid sedentary behavior
<b>Social Liberation</b>	Realizing that the social norms are changing in the direction of encouraging less sedentary time	I notice society changing in ways that help to reduce sedentary time
<i><b>Behavioral Processes</b></i>		
<b>Contingency Management</b>	Rewarding one's self or being rewarded by others for reducing sedentary time	I do reward myself when I make efforts to reduce sedentary time
<b>Counter Conditioning</b>	Substituting alternatives for sedentary behavior	I do something else instead of being sedentary when I need to relax or deal with tension
<b>Helping Relationships</b>	Seeking social support for reducing sedentary behavior	I have someone who encourages me not to be sedentary when I am
<b>Self-liberation</b>	Making a firm commitment to reduce sedentary time	I tell myself that I need to reduce sedentary time
<b>Stimulus Control</b>	Avoiding stimuli that remind sedentary behavior	I remove things that contribute to my sedentary behavior

and expressed as "activity counts (cts)," which describe the amplitude and frequency of detected accelerations. Recorded data were screened for wear time and time spent per day sedentary was defined as  $< 100 \text{ cts} \times \text{min}^{-1}$ . Daily sedentary time estimates ( $\text{min} \cdot \text{d}^{-1}$ ) were averaged across valid wear days ( $\geq 10 \text{ hours} \cdot \text{d}^{-1}$ ) in all participants with at least 4 of 7 valid days.<sup>19,20</sup> The validity and reliability of the GT3X+ accelerometer has been described previously.<sup>21</sup>

**Strategic constructs of the TTM.** We used a processes of change questionnaire for sedentary behavior to identify the differential use of processes based on the participants' current sedentary time. The questionnaire consisted of 40 items including a set of 4 items assessing each of the 10 processes of change (5 cognitive and 5 behavioral processes). The frequency of use was measured with a 5-point Likert scale from 1 (never) to 5 (repeatedly). Self-

efficacy scores were assessed using a 6-item situational confidence scale modified for sedentary behavior. Participants were asked how confidently they could break a prolonged sedentary behavior bout in each of the 6 situations. Each item was scored on a 5-point Likert scale from 1 (not at all confident) to 5 (extremely confident). Lastly, we used a decisional balance questionnaire to identify how important each statement of pros and cons was with respect to the individual's decision of whether to avoid sedentary time or not. The scale consisted of 12 items including 6 pros and 6 cons for being sedentary with a 5-point Likert scale from 1 (not at all important) to 5 (extremely important). The validity and reliability of the TTM for sedentary behavior were described previously (eg, Cronbach alphas from .73 to .88; Intra-class correlation coefficients ranging from .80 to .94).<sup>15</sup>

**Table 2**  
**Demographic Characteristics**

Variables	Quintiles of Average Sedentary Time				
	1 ( $< 376.6$ minutes/week)	2 ( $376.6-445.8$ minutes/week)	3 ( $445.9-505.6$ minutes/week)	4 ( $505.7-580.4$ minutes/week)	5 ( $> 580.4$ minutes/week)
<b>Age (years)</b>	20.5 ± 1.8	20.7 ± 1.8	20.3 ± 2.1	20.3 ± 2.8	20.2 ± 1.5
<b>BMI (kg/m<sup>2</sup>)</b>	24.2 ± 3.3	23.3 ± 3.1	23.9 ± 3.0	23.6 ± 2.9	24.0 ± 3.6
<b>Sex</b>					
Male	22	25	19	20	18
Female	19	15	21	19	23
<b>Ethnicity</b>					
White	15	16	15	15	13
Black	3	5	9	2	2
Hispanic	10	10	10	13	15
Asian	13	9	6	9	11
<b>College Year</b>					
1	1	0	3	1	2
2	18	10	16	17	16
3	10	12	14	13	13
4	12	18	7	8	10
<b>Sedentary Time (minutes/day)</b>	317.7 ± 41.8	411.3 ± 21.2	478.1 ± 19.7	543.0 ± 20.5	690.2 ± 135.0

Note.

Values are means ± standard deviation or frequency; BMI = Body Mass Index

## Data Analysis

We computed descriptive statistics for demographics and relevant variables presented as means, standard deviations, and frequencies. To facilitate direct comparison with stage of change, we categorized the averaged sedentary time estimate into quintiles. Multivariate analyses of variances (MANOVAs) with *post hoc* pairwise comparisons were conducted to determine mean differences in processes of change, self-efficacy, and decisional balance across quintiles of sitting time. Tests for linear trends were conducted using orthogonal polynomial coefficients. A 2-sided  $p < .05$  was considered statistically significant. All data management and statistical analyses were conducted using IBM SPSS version 23.

## RESULTS

Table 1 reports the descriptive characteristics of

the participants. Average sedentary time was categorized into quintiles. The lowest group (1<sup>st</sup> quintile) were sedentary for  $317.7 \pm 41.8$  minutes/day while the highest group (5<sup>th</sup> quintile) were sedentary for  $690.2 \pm 135.0$  minutes/day.

Table 2 shows the mean scores of the strategic constructs of the TTM for sedentary behavior across quintiles of average sedentary time. Overall, both cognitive and behavioral processes were significantly different across quintiles of sedentary time ( $F[4,196] = 4.35$ ,  $p = .002$  and  $F[4,196] = 6.38$ ,  $p < .001$ , respectively). Eight out of 10 constructs (ie, consciousness raising, dramatic relief, social liberation, contingency management, counter conditioning, helping relationships, self-liberation, and stimulus control) were used significantly more frequently by the participants in the lowest quintile of sedentary time than those in the higher quintiles.

**Table 3**  
**Mean Scores of the TTM Constructs across Quintiles of Sedentary Time**

Construct	Quintiles of Average Sedentary Time					F	Post hoc	$\eta^2_p$	P <sub>trend</sub>
	1 (Lowest) (N = 41)	2 (N = 40)	3 (N = 40)	4 (N = 39)	5 (Highest) (N = 41)				
<b>Cognitive Processes</b>	2.8 ± 0.5	2.7 ± 0.5	2.3 ± 0.7	2.6 ± 0.6	2.5 ± 0.6	4.4*	1/2>3	.08	.004
Consciousness Raising	2.2 ± 0.7	2.1 ± 0.7	1.7 ± 0.8	1.9 ± 0.7	1.7 ± 0.6	4.6*	1>3/5	.09	.001
Dramatic Relief	2.7 ± 0.8	2.8 ± 0.9	2.2 ± 0.9	2.7 ± 0.9	2.5 ± 0.7	3.4*	2>3	.07	.277
Environmental-Reevaluation	2.7 ± 0.7	2.8 ± 0.7	2.4 ± 0.9	2.6 ± 0.8	2.5 ± 0.8	2.5		.05	.043
Self-reevaluation	3.3 ± 0.7	3.3 ± 0.7	3.0 ± 0.9	3.2 ± 0.9	3.2 ± 0.8	1.5		.03	.234
Social Liberation	3.0 ± 0.7	2.6 ± 0.7	2.3 ± 0.9	2.5 ± 0.7	2.4 ± 0.7	4.5*	1>3/4/5	.08	.001
<b>Behavioral Processes</b>	2.9 ± 0.5	2.6 ± 0.5	2.4 ± 0.7	2.5 ± 0.5	2.5 ± 0.5	6.4*	1>3/4/5	.12	< .001
Contingency Management	3.2 ± 0.9	2.7 ± 0.8	2.5 ± 1.1	2.6 ± 0.8	2.6 ± 0.8	4.3*	1>3/4/5	.08	.001
Counter Conditioning	3.4 ± 0.8	3.1 ± 0.7	3.0 ± 0.9	2.9 ± 0.7	2.9 ± 0.7	3.5*	1>4/5	.07	< .001
Helping Relationships	2.3 ± 0.7	2.2 ± 0.7	1.8 ± 0.8	2.1 ± 0.8	2.0 ± 0.7	3.1*	1>3	.06	.023
Self-liberation	3.5 ± 0.6	3.1 ± 0.8	2.8 ± 0.9	3.0 ± 0.8	3.2 ± 0.8	4.1*	1>3	.08	.045
Stimulus Control	2.1 ± 0.6	2.0 ± 0.7	1.7 ± 0.7	1.8 ± 0.6	1.7 ± 0.5	3.9*	1>3/5	.07	< .001
<b>Self-efficacy</b>	3.0 ± 0.8	2.7 ± 0.9	2.7 ± 0.8	2.8 ± 0.7	2.9 ± 0.8	0.8		.02	.674
<b>Decisional Balance</b>	1.1 ± 0.9	1.0 ± 1.2	0.8 ± 1.2	0.7 ± 0.9	1.1 ± 0.9	1.3		.03	.315
Pros	3.8 ± 0.7	3.8 ± 0.7	3.5 ± 0.9	3.6 ± 0.7	3.7 ± 0.8	1.2		.02	.361
Cons	2.7 ± 0.6	2.8 ± 0.8	2.6 ± 0.7	3.0 ± 0.6	2.6 ± 0.6	2.1		.04	.631

Note.

Values are means ± standard deviation; TTM = Transtheoretical Model. \* $p < .05$

No statistically significant differences were found across quintiles in other processes, such as environmental reevaluation and self-reevaluation. Based on Cohen's classification, the process of consciousness raising showed the largest effect size (ie,  $\eta^2_p = .09$ ) followed by social liberation, contingency management and self-liberation (ie,  $\eta^2_p = .08$  for all 3 processes) among the 10 processes of change.

In addition, significant linear trends ( $p_{\text{trend}} < .05$ ) in mean scores of the TTM core construct across quintiles of sedentary time were found in the following processes: consciousness raising, environmental reevaluation, social liberation, contingency management, counter conditioning, helping relationships, self-liberation, and stimulus control. In general, people with lower sedentary time more frequently used the aforementioned processes compared to those who had a higher sedentary time.

The average scores of self-efficacy to avoid prolonged sedentary behavior were not significantly dif-

ferent across quintiles of sedentary time ( $F[4,196] = 0.82$ ,  $p = .512$ ). In addition, no statistically significant difference in the scores of decisional balance were found across the quintiles ( $F[4,196] = 1.26$ ,  $p = .286$ ). Both scores of pros and cons of reducing sedentary time were not significantly different across the quintiles ( $F[4,196] = 1.20$ ,  $p = .314$  and  $F[4,196] = 2.09$ ,  $p = .082$ , respectively). Both self-efficacy and decisional balance indicated small effect size.

## DISCUSSION

In the present study, we investigated the differential use of the strategic constructs of the TTM across accelerometer-determined sedentary time. The results indicated that most processes of change were used more frequently in the lowest quintile of sedentary time (lower accumulated sedentary time) than those in the higher quintiles (incrementally

higher accumulated sedentary time). We also observed significant linear trends ( $p_{\text{trend}} < .05$ ) in the mean scores of most cognitive and behavioral processes (8 out of 10) across the quintiles of sedentary time. The constructs of self-efficacy and decisional balance were not differentially used in relation to the participants' sedentary time.

A novel approach of the current study is that the use of the strategic constructs of the TTM associated with sedentary behavior was examined based on the objective measurement of the behavior instead of using stages of change. The primary limitation with this approach centers on possible misclassification of stage classification when arbitrary stage definitions are used.<sup>17</sup> Stage classification is typically processed by asking a set of dichotomous (yes/no) questions about current behavior status and readiness (ie, intention) to change the behavior. For instance, participants are asked whether they are currently engaged in the targeted behavior. If the participant is not currently engaged in the targeted behavior, s/he is asked if they intend to change the behavior within a specified period (ie, next 30 days or 6 months). If the participant is already engaged in the targeted behavior, s/he is asked how long the behavior or changed behavior has been maintained. To address this limitation, some past studies modified the way of explaining the stages of change for their target behavior (eg, physical activity). Marcus et al<sup>22</sup> incorporated the governmental physical activity guidelines into the questions about stages of change for physical activity, and the additional information determining the guideline compliance made the stage classification more valid, especially for distinguishing between pre-action stages (ie, precontemplation through preparation stages) and action-oriented stages (ie, action and maintenance stages). Given that neither a guideline for sedentary behavior nor a recommended amount of daily sedentary time to attenuate risk of chronic disease and disability has been identified,<sup>1</sup> this study and use of accelerometer-determined sedentary behavior is well-positioned to address this important research gap. The findings of this study ensure the potential utility of the strategic constructs of the TTM for reducing sedentary behavior and support the stage classification for sedentary behavior providing similar results in the construct use.<sup>15</sup> The criticism on the accuracy of stages of change may be applicable to a specific behavior (eg, quitting smoking) in a

certain setting, and researchers and practitioners have to address the criticism when aiming to change such behaviors using stages of change.

Despite the potential ability of the processes of change to promote behavior change, it has been minimally utilized by researchers in most intervention studies. The processes of change were originally derived from a comparative analysis of 18 leading models of psychotherapy and consist of 10 independent processes including 5 cognitive processes and 5 behavioral processes.<sup>23</sup> Although the temporal relationship of the processes of change (ie, a strong relationship between the cognitive processes and earlier stages vs. the behavioral processes and later stages) was commonly posited in the TTM, the relationship is not always consistent across behaviors, contexts and populations.<sup>16,24,25</sup> Based on the results of the current study, participants who had a less sitting time used both cognitive and behavioral processes more frequently compared to those who were highly sedentary with the exception of 2 processes including: environmental reevaluation and self-reevaluation. Furthermore, larger differences in the scores of processes of change between the quintiles (eg, higher scores in groups characterized by less accumulated sedentary time) were observed in the processes of consciousness raising, social liberation, contingency management and self-liberation suggesting that such processes may have a greater effect to change sedentary behavior rather than other processes. With the exception of the 2 processes, self-reevaluation was the only process that showed both non-significant mean differences in the score of the process and non-significant linear trends across the quintiles of sedentary time. Self-reevaluation hereto refers to one's appraisal of the values in relation to avoid sedentary behavior. The example questions include the following statements: "Reducing my sedentary time would make me a healthier and happier person" and "I feel more competent myself when I decide to avoid sedentary behavior."<sup>15</sup> Ironically, our results showed that the average scores of the process of self-reevaluation were higher across the quintiles compared to other processes indicating the participants (ie, college students) highly valued the consequences of avoiding sedentary behavior regardless of their actual time spent sedentary. In other words, even though the college students recognized the benefits of avoiding sedentary behavior, they remained sedentary for most of the day. This

finding may reflect the most common enabler for sedentary behavior, time constraints associated with school and works in the college setting;<sup>26,27</sup> therefore, one should be cautious when using the process of self-reevaluation for reducing sedentary time for college students.

Unlike the previous study using the stage classification (ie, stage of change) based on the intentions of avoiding sedentary behavior in TTM,<sup>16</sup> we observed non-significant differences in the scores of self-efficacy and decisional balance across the quintiles of sedentary time. The scores of self-efficacy in the current study were relatively high regardless of sedentary time. Self-efficacy refers to confidence in an individual's ability to perform a particular task (eg, avoiding sedentary behavior).<sup>28</sup> Given that the degree of confidence is specific to a challenging behavior, it would be more suitable to compare this finding to other studies examining the relationship between self-efficacy and accelerometer-determined sedentary time, but no other studies have examined these relations for comparison. Nonetheless, this finding might be explained by the gap between perception and action. There exists a clear link between confidence and competence.<sup>29</sup> For example, individuals tend to feel more competent when they have confidence in performing a particular task. However, this does not necessarily mean that confidence equates to competence, but it could be considered as a crucial influence on competent performance. Individuals can be overconfident in performing a specific behavior if they are unaware of their practical ability to perform the behavior.<sup>30,31</sup> A lack of experience in avoiding sedentary behavior or an underestimation of the common barriers to reduce sedentary time in college life may be attributable to such high scores of self-efficacy, even in the high quintiles, in this study. Likewise, a similar pattern was observed in the score of decisional balance. Decisional balance indicates individual's weighting of the perceived advantages and disadvantages of avoiding sedentary behavior, which has similar aspect to the aforementioned process of change, self-reevaluation. Again, despite the awareness of pros/cons of avoiding sitting time, most of the college students spent a majority of waking hours, sedentary. The inevitable nature of prolonged sedentary time in the college setting (eg, taking classes or studying/using computer at desk) might hinder students from reducing sedentary time,<sup>32</sup> although it is possible during non-discretionary periods of the

day. Further research is warranted to improve understanding of the relationship between these variables.

Several limitations of this study should be considered. Our sample of college students was one of convenience. This may limit the generalizability of the findings to more diverse populations, or across the life-course. In addition, summary estimates characterizing sedentary time were quantified based on accumulated time at < 100 counts, without consideration of anatomical positioning (ie, standing, sitting, or lying down). Future research in this area should consider use of postural recognition devices (eg, ActivPAL) to confirm these findings. Furthermore, the current study was a cross-sectional analysis, which is unable to confirm sedentary time over time and precludes causal inference for the association between the variables. Lastly, using self-report for the strategic constructs may not reflect participants' true conditions. Nevertheless, no objective assessment is available to measure the constructs, and the questionnaires we used in the present study was previously validated.<sup>15</sup>

## Conclusion

In the current study, we examined college students' differential use of strategic constructs of the TTM across accelerometer-determined sedentary time. Among the strategic constructs of the TTM, the processes of change were used differently across the quintiles of sedentary time. Specifically, participants with less sedentary time more frequently used most of the processes of change compared to those who were more highly sedentary. However, self-efficacy and decisional balance were not associated with accelerometer-determined sedentary time. Our results revealed additional associations between the strategic constructs of the TTM. Particularly, several intervention methods such as awareness raising, incentivization, self-motivation, and social norm building can be suggested as effective strategies for reducing sedentary time in college students for future research. Further studies are needed with other populations to clarify these associations.

## Human Subjects Approval Statement

This study was approved by the University of Texas at Austin Institutional Review Board. Informed consent was obtained from all participants included in the study.

## Conflict of Interest Statement

The authors have no conflict of interest to declare.

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