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Assessing Energy Level as a Marker of Aerobic Exercise Readiness: A Pilot Investigation

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ABSTRACT

International Journal of Exercise Science 10(1): 62-75, 2017. Energy ratings have been used as a marker of exercise readiness (i.e. pre-exercise physical/mental state indicating ability to perform) within flexible nonlinear periodization (FNLP)-based resistance training interventions. However, empirical data is lacking regarding the utility of this approach for aerobic exercise. The purpose of this study was to examine the ability of pre-exercise energy level to predict affective and behavioral responses to prescribed aerobic exercise. Participants consisted of 19 women and 8 men (N=27, age=20±4 years, estimated maximal oxygen uptake=37±6). Participants performed two 30-min bouts of treadmill exercise under an imposed moderate intensity (70-75% of age-predicted maximal heart rate; %HRmax) condition and a self-selected intensity condition. Pre-exercise energy level was assessed using the Energy Index (EI) score derived from the Profile of Mood States. Feeling Scale (FS) was the dependent variable in the imposed bout and average intensity (%HRmax) was the dependent variable during the self-selected bout. Multiple regression analyses were used to determine if EI predicted mean FS and %HRmax. After controlling for potential confounders, EI significantly predicted mean FS (β=.499, p=.037) during imposed exercise. No significant relationship existed between EI and overall intensity (β =-121, p=.554) during self-selected exercise. While EI predicted in-task core affect it was unrelated to self-selected intensity. It is premature to suggest EI as an optimal predictor of exercise readiness in regards to aerobic exercise for aerobically untrained young adults. More research is needed to determine an evidence-based marker of readiness that can be used for aerobic exercise prescribed within the context of FNLP.

KEY WORDS: Core affect, acute treadmill exercise, self-paced exercise

INTRODUCTION

Periodization of training workloads (i.e. systematic variety in exercise frequency, intensity, duration, and mode over time) is widely implemented for athletes (9-12, 50). The goal of various periodization models is to develop appropriately timed peak performance, minimize risk of injury, and prevent overtraining to promote long-term adherence (20, 27, 30, 51). In a recent systematic review, researchers suggest that periodized training has been safely implemented in sedentary adults, yielding improvements in relevant health and fitness outcomes (52). However, a major gap in this literature is that periodized approaches are rarely applied to aerobic exercise interventions. More research in this area is warranted because, despite the documented health benefits, the majority of adults engage in insufficient volumes of aerobic activity (53) and long term adherence is poor (39). Based on its successful application in athletes, it is possible that periodized aerobic exercise prescriptions may improve behavior to a greater degree compared to the relatively uniform prescriptions typically applied.

Flexible nonlinear periodization (FNLP) is likely the most appropriate model to apply within sedentary populations. Unlike other periodization models (e.g. linear, undulating, block), FNLP requires the program to be responsive to the individual undergoing training. That is, acute bouts of exercise are matched in response to an individual's physical and/or mental readiness to train on a given day, such that more demanding workouts are completed in response to high readiness, and less demanding workouts are completed in response to low readiness (28). A variation is to allow individuals to choose which bout to complete (from options ranging from low to high demand) based on self-gauged perceptions of readiness. While the practicality of such an approach is apparent, FNLP offers a means to apply relevant behavioral constructs. First, allowing individuals to choose bouts may enhance perceptions of autonomy, which is associated with improved behavior in accordance with Self Determination Theory (7). Second, by allowing individuals to match bouts to pre-exercise state (e.g. avoiding high demand workouts on low readiness days), FNLP-based prescriptions may promote more positive affective responses (e.g. degree of pleasure or displeasure). A growing body of literature suggests that imposing exercise workloads has a negative impact on in-task affect (15, 32, 56), which predicts lower exercise in the future (57, 58). While these hypotheses have yet to be empirically tested in the context of FNLP, a previous study (36) found that flexible goal-setting within a walking/jogging course for inactive adults (i.e. modification of daily distance goal based on how individuals felt each day) improved exercise behavior, compared to participants receiving fixed distance goals imposed by instructors. Although no information was provided regarding which feelings were measured or how they were assessed, this study lends some support for a flexible, participant-driven exercise prescription.

Prior to adapting and implementing FNLP for aerobic training interventions, it is important to determine an appropriate marker of readiness. To date, two published studies have implemented FNLP for resistance training (37, 38). Both recruited inactive college students, allowing them to choose pre-determined bouts of resistance exercise based on their energy level rated on a scale from 0 (no energy) to 10 (fully motivated with maximum energy). While no rationale was explicitly provided for this scale, assessment of energy level may be considered a potential means of condensing Kraemer and Fleck's six-step approach to determine readiness introduced in their foundational text (28). These steps include 1) interactions with the trainee, 2) injury status, 3) hydration, 4) mental/physical fatigue ratings,

5) performance of a physical task (e.g. vertical jump), and 6) initial performance of the assigned training workload. It is reasonable to speculate that an individual's energy level would influence or be influenced by each of these components. Although both studies noted significant physiological improvements, several concerns exist. First, the low anchor only relates to energy, whereas the high anchor relates to both motivation and energy, which potentially reduces the construct validity of the measure. Second, neither study provided data indicating whether energy ratings were actually related to any acute performance variables or relevant psychological responses. Third, it is unknown whether this approach is translatable to aerobic exercise behavior as both studies addressed resistance training. Thus, while energy levels are a plausible marker of exercise readiness, more empirical evidence is necessary to demonstrate that these ratings are predictive of relevant psychological and behavioral aspects of aerobic exercise.

The theoretical basis of FNLP is that individuals reporting greater degrees of readiness are better suited to engage in higher demand bouts. In regards to aerobic exercise, we hypothesize that higher energy levels should predict more positive affective responses during moderate-intensity treadmill walking. We also hypothesized that higher energy would predict greater self-selected exercise intensity. Energy was operationalized using the Energy Index (EI), which is calculated by subtracting fatigue from vigor subscale scores of the Profile of Mood States (POMS). This measure of energy was chosen for three reasons. First, POMS vigor and fatigue scores show the greatest changes in response to exercise training (41, 45). Second, EI has been used in previous research studies aiming to measure changes in energy with exercise training stress and recovery (8, 26). Third, currently there is no measure validated to assess the construct of exercise readiness as it relates to FNLP. Thus, we chose to assess a measure of energy to be consistent with previous FNLP-based intervention research. The primary purpose of the current study was to determine the ability of pre-exercise energy index to predict 1) affective responses during an imposed bout of moderate intensity aerobic exercise, and 2) mean intensity during a self-selected bout of aerobic exercise.

METHODS

Participants

All procedures were approved by the University of Tennessee Institutional Review Board (IRB# 9521B) regarding ethics and human subject's protection. Undergraduate and graduate university students were recruited as a convenience sample for this pilot study. Participants were recruited using flyer advertisements distributed throughout the University campus, email listservs, and classroom announcements. All participants provided written informed consent prior to enrollment. Individuals were considered eligible if they were between the ages of 18 and 35 years, had a measured body mass index (BMI) of less than 35 kg/m^2, and self-reported less than 90 minutes of structured, moderate-intensity aerobic activity per week (or the metabolic equivalent). Additional exclusion criteria included one or more contraindications to beginning an exercise program according to the Physical Activity Readiness Questionnaire (PAR-Q), or pregnant / planning to become pregnant. Twenty-seven participants completed all three sessions and were included for statistical analyses. Table 1. contains descriptive statistics for demographic characteristics.

Table 1. Baseline sociodemographic characteristics

	Participants (N=27) Mean ± SD or %
Age (years)	20.52±4.30
BMI (kg/m^2)	24.14±3.81
Estimated VO_{2max} (ml/kg/min)	37.36±5.80
Women	70.37%
Non-Hispanic White	70.37%

BMI = body mass index, VO_{2max} = maximal oxygen uptake

Protocol

Eligible participants completed an orientation visit that included baseline demographic and psychological trait questionnaires, measures of height and weight, and a graded exercise test to estimate maximal oxygen uptake (VO_{2max}). Participants then completed two additional visits occurring in a randomized order, with at least 48 hours between visits: 1) imposed intensity condition (to determine ability of EI to predict affective responses to a standardized intensity, and 2) self-selected intensity condition (to determine ability of EI to predict volitional intensity).

During the baseline visit, participants completed the following questionnaires to assess variables that may potentially influence behavioral and psychological responses during the study: basic demographic information (age, gender), Cohen's Perceived Stress Scale (PSS), the Behavioral Regulations in Exercise Questionnaire-2 (BREQ-2), the Physical Activity Enjoyment Scale (PACES) and the Preference for and Tolerance of Exercise Intensity Questionnaire (PRETIE-Q). Height and weight were measured using standard procedures to calculate BMI.

Next, eligible participants were fitted with a heart rate monitor (Polar Electro, Lake Success, NY) and completed an incremental peak treadmill test to estimate VO_{2max}. This session also served to familiarize participants with treadmill walking, as well as in-task scales, prior to experimental sessions. The exercise test followed a modified Balke protocol, with heart rate (HR) and rating of perceived exertion (RPE) measured during the last 10 seconds of each minute. Participants began walking at 3.3 mph at 0% grade. After the first minute, the incline increased to 2% and continued increasing by 1% each minute, for a maximum of 25 minutes. Peak termination criteria included a recorded HR within 10 bpm of age-predicted maximal HR and >18 on the Borg RPE scale. Time on the treadmill was recorded when both criteria were met. Time on the treadmill with this protocol is highly correlated with VO_{2max} in both men (43) and women (44). Estimated VO_{2max} was calculated using the formula: VO_{2max} = 1.44 x (minutes on treadmill) + 14.99 (43).

Following the graded exercise test, participants were scheduled to complete the two experimental conditions, imposed intensity and self-selected intensity, in a randomized order and separated by at least 48 hours. For both supervised exercise sessions, participants reported that they abstained from heavy exertion for 24 hours prior to each session, as well as alcohol and caffeine for at least four hours prior to each session. Pre-exercise EI was recorded immediately prior to the exercise bout. For both sessions, heart rate was recorded each minute while RPE, and Feeling Scale (FS; measure of core affect) were recorded immediately before exercise, during the last 10 seconds of each five-minute block, and immediately after exercise. Participants were blinded to the treadmill settings and time for both conditions by placing a custom-fit barrier to block to the display screen.

The imposed intensity condition included a 30-minute bout where treadmill speed was set to 3.3 mph at a grade that elicited a heart rate between 70-75% of age-predicted HR_{max} (moderate intensity). Intensity was based on age-predicted HR_{max} because the graded exercise test was designed to test peak capacity and true HR_{max} values were not determined. Mean FS was calculated using measurements taken at minutes 5, 10, 15, 20, 25, and 30.

The self-selected intensity condition included a 30-minute bout during which participants were allowed 10 seconds to self-select treadmill speed and/or grade using the handrail controls at minutes 0, 5, 10, 15, 20, and 25. Participants were given the instruction "at this point you are allowed to adjust speed, grade, or both in the direction you prefer. Additionally, you are free to keep the settings exactly the same". Language that could potentially bias participants was avoided (e.g. "choose a setting that feels good"). Settings were recorded at each 5-minute interval. Minute-to-minute heart rates were averaged across the 30 minutes, and then divided by age-predicted maximal heart rate to determine average intensity of the bout, expressed as $\%HR_{max}$.

Participants were asked to consider how often they experienced stressful thoughts or feelings over the previous month (e.g., "In the past month, how often have you been upset because of something that had happened unexpectedly?"). The PSS consists of 10 items rated by frequency on a 5-point likert scale (1=never, 5=very often) (6).

Participants were be asked to rate how they feel at the present moment about physical activity in general. The PACES consists of 18 items that are rated on a 7-point Likert scale with opposite descriptions at each end (1=I enjoy it or it makes me depressed, 7=I hate it or It makes me happy) (25).

The BREQ-2 assesses self-determined motivation towards physical activity. Participants were asked to indicate to what extent each of the items is true for them in general. 19 items were scored on a 5-point Likert scale (0=not true for me, 2=sometimes true for me, 4=very true for me). The BREQ-2 was scored by compiling separate mean subscale scores and by computing the Relative Autonomy Index (RAI), with higher scores indicating more autonomy-driven regulation (35).

The PRETIE-Q was used to assess individual differences regarding the intensity of exercise preferred and the intensity that can be tolerated. 16 items were scored on a 5-point Likert Scale (1=totally disagree, 3= neutral, 5= totally agree) (19).

Participants were asked describe how they felt immediately before each exercise session (using the prompt "right now") to assess vigor and fatigue subscales of the Profile of Mood States. Items were rated by the extent to which each is felt using a 5-point Likert Scale (0= not at all, 1=a little, 2=moderately, 3=quite a bit, 4=extremely). The instruction "right now" can assess transitory psychological states (2, 34). EI is calculated by subtracting the score for fatigue (7 items) from that of vigor (8 items), with scores ranging between -28 and 32.

This FS is an 11-point scale that assesses immediate affective feelings of pleasure and displeasure. The FS ranges from -5 (very bad) to 5 (very good) with 0 (neutral) as the midpoint (24, 46).

RPE was measured on the 6-20 Borg Scale (7=very, very light, 9=very light, 11=fairly light, 13=somewhat hard, 15=hard, 17=very hard, 19=very, very hard (3). Prior to each exercise bout, participants were instructed on how to rate RPE using the standard script supported by the American College of Sports Medicine.

Statistical Analysis

All analyses were conducted using the Statistical Package for the Social Sciences (SPSS, version 21; SPSS Inc., Chicago IL). Bivariate correlation analyses were completed in order to determine relationships between independent (EI) and dependent (FS, self-selected intensity) variables. Two separate multiple regression analyses were conducted. The first assessed the relationship between EI and mean FS during the imposed exercise condition. The second assessed the relationship between EI and average intensity (%HR_{max}) during the self-selected condition.

RESULTS

Table 2. contains descriptive statistics for primary independent and dependent variables. Mean exercise intensity fell within the ranged prescribed for the imposed condition with low variability (range: 70.60-74.70% HR_{max}). While mean intensity was similar for the self-selected condition, a higher inter-individual variability was noted (range: 54.23-92.63% HR_{max}). Inter-individual variability was also relatively high for pre-exercise EI in both conditions (imposed range: -11 to 27, self-selected range: -11 to 26).

Bivariate correlation analyses indicated that EI was strongly and positively correlated with mean FS ($r=.569$, $p=.002$) but not bout intensity expressed as %HR_{max} ($r=-.224$, $p=.262$), as indicated in Figure 1. The potential heteroscedastic relationship between EI and FS was objectively tested using both the Glejser and Breusch-Pagan methods and no concerns were noted (Glejser $p=0.38$, Breusch-Pagan $p=0.62$).

Table 2. Primary independent and dependent variables (Mean±SD)

	Imposed Intensity Condition	Self-Selected Intensity Condition
Pre-Exercise EI	7.59±9.20	7.26±8.75
Mean FS	3.05±1.25	3.11±1.30
Mean RPE	9.90±2.07	10.86±2.61
Mean %HRmax	74.70±0.95	73.10±9.90

EI = energy index, FS = feeling scale, RPE = rating of perceived exertion, %HRmax = intensity defined as percent of age-predicted maximal heart rate.

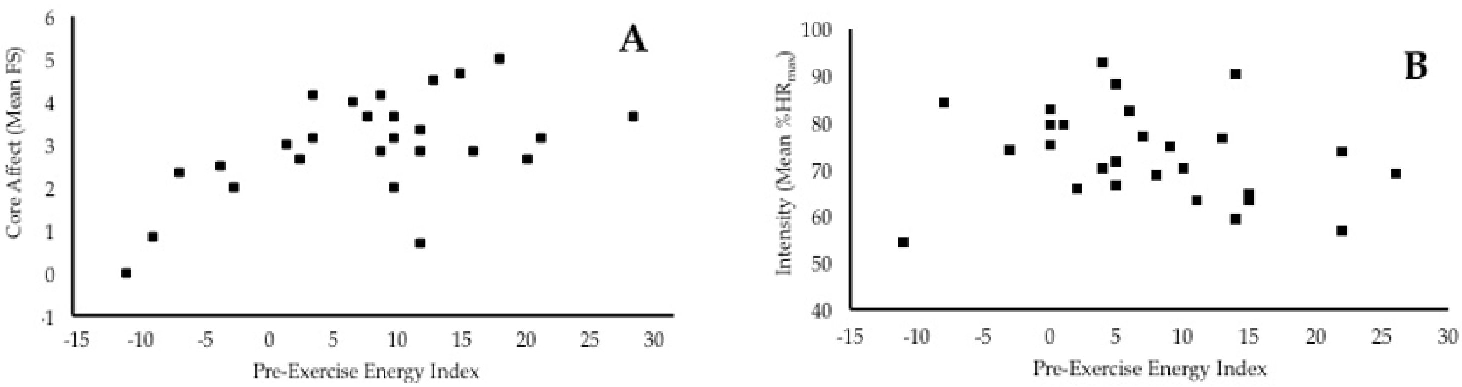

Figure 1. Energy index, in-task affect, and self-selected intensity. Relationships between pre-exercise energy index and mean feeling scale during moderate-intensity treadmill walking (Panel A, imposed condition) and mean intensity expressed as percentage of age-predicted maximal heart rate (Panel B, self-selected condition) in individuals completing all study conditions (N=27).

Table 3. illustrates the results of the multiple regression analyses. The first regression examined the relationship between EI, mean FS during imposed exercise that was standardized at moderate intensity across participants. The second regression examined the relationship between EI and intensity (mean $\%HR_{max}$) across the self-selected bout. After adjustment for Age, BMI, VO_{2max}, RAI, PSS, PACES, and PRETIE-Q, EI was significantly associated with mean FS (β=.499, p=.037) measured during imposed exercise. No significant associations were found between EI and self-selected intensity represented as $\%HR_{max}$ (β=-.121, p=.554).

DISCUSSION

The aim of the current study was to determine the ability of pre-exercise energy level to predict relevant affective (Feeling Scale) and behavioral (self-selected exercise intensity) outcomes surmised to be impacted by one's readiness to exercise. When controlling for relevant factors, greater pre-exercise EI predicted more positive affective responses during imposed intensity exercise. However, no significant relationship was found between EI and self-selected exercise intensity (p=.554).

Table 3. Multiple regression examining relationship between independent (EI) and dependent variables

	Mean FS (β)	% HR_{max} (β)
Estimated VO_{2max}	.021	.335
BMI	.019	.351
Age	-.411	.389
RAI	.114	.127
PSS	.325	.109
PACES	.207	-.174
PRETIE-Q[a]	-.047	.360
PRETIE-Q[b]	.023	-.137
EI	.499*	-.121

FS = feeling scale (measured during imposed moderate exercise), %HRmax = percent of age-predicted maximal heart rate (measured during self-selected exercise), BMI = Body Mass Index, RAI = Relative Autonomy Index, PSS = Perceived Stress Scale, PACES = physical activity enjoyment scale, PRETIE-Q[a] = Tolerance of exercise intensity, PRETIE-Q[b] = Preference for exercise intensity, EI = energy index, *p<0.05.

Average values regarding affective responses to moderate-intensity aerobic exercise and self-selected exercise intensity aligned with prior research (15, 16, 33, 42, 54, 58). In the current study, FS values suggest that individuals generally report positive, rather than negative, affective responses to imposed continuous moderate intensity aerobic exercise. Mean values reported here are similar to recent studies (ranging between 2.6 and 3.0) (33, 42, 54, 58). Similarly, average self-selected intensity fell within the range of moderate intensity, which has been demonstrated in prior research (15, 16). Mean EI values reported were lower relative to values observed in athletic populations prior to any overreaching training or acute event (range between 14 and 18) (8, 22, 26). This disparity is expected, as healthy athletes tend to score higher on vigor and lower on fatigue, tension, depression, anger, and confusion, when compared to the general population (i.e. the "iceberg profile") (40).

It is also important to examine intra-individual differences in regards to physiological and psychological responses to exercise. The observed intra-individual variability in mean FS is in line with prior research (14, 55, 57). Of the individuals who completed the imposed exercise bout, 11% exhibited an increase in affect, 63% exhibited a decrease in affect, and 26% indicated no change in affect, relative to pre-exercise FS. Corresponding values in the self-selected condition were found to be 11%, 67%, and 22%, respectively. Regarding self-selected exercise intensity, 19% bouts fell within the range for low intensity (<64% HR_{max}), 44% were moderate intensity (64-76% HR_{max}), and 37% were high intensity (>76% HR_{max}). Such variability has also been observed with self-selected exercise intensity (17). Given our observations of both mean and individual responses reflect previous research, we believe that the current study design was appropriate as an acute exercise readiness paradigm, given the relative lack of empirical evidence in this area of research.

Because only one out of the two hypotheses was supported in the current study, it is premature to suggest that measuring one's EI alone is a sufficient measure of exercise readiness as it relates to aerobic exercise for aerobically untrained young adults. Given the aforementioned relationship between in-task affect and future exercise behavior (58), the ability to predict such responses to moderate-intensity walking is important. First, walking is the most commonly reported mode of physical activity in American adults (23). Second, moderate intensities are consistently prescribed, as they result in substantial health benefits and pose a lower risk of musculoskeletal injuries and acute cardiac events (1). However, the practicality of using energy index within interventions for sedentary adults is unknown. One concern is that, nearly one quarter of U.S. adults report persistent fatigue (5, 29). In this regard, using a measure of energy as the sole marker of readiness may not allow optimal implementation of a FNLP-based program in this population. Given that exercise is a complex human behavior, influenced by interrelated physiological, psychological, and environmental factors (49), more research is likely required to determine optimal adaptation of FNLP for untrained populations.

Although the primary analyses indicated no significant relationship between EI and mean self-selected intensity, further analyses revealed information that will inform future research aiming to optimize FNLP for aerobic exercise. The current study utilized a randomized, counter-balanced design, as this approach is typically considered to be more robust. However, this appears to have impacted self-selected exercise behavior. Although it has been suggested that inexperience may lead individuals to self-select higher intensities (16), it is unclear how much experience or familiarization may be necessary to counter this effect. Because 52% of the participants experienced a graded exercise test (spanning low to high intensity) and a 30-minute moderate intensity bout prior to being prompted to self-select treadmill settings, we examined the data for potential order effects. Individuals who completed the self-selected bout first (n=13) chose higher intensities relative to individuals who completed the self-selected bout second (n=14) (76.60±10.02 vs. 69.86±8.92 %HR_{max}; t=1.85, p=.076). While this analysis was likely underpowered, it is striking to note that 54% of participants in the former group self-selected exercise that is characterized as high intensity based on heart rate responses, compared to 21% who choose high intensities in the latter group. Additionally, those who completed the self-selected condition first reported significantly less positive affective responses relative to those who completed it second (2.42±1.43 vs. 3.75±0.74; t=-2.98, p=.008). Based on these observations, we conducted additional bivariate correlations within each subset of participants. These analyses revealed that EI was significantly related to self-selected intensity in those who performed the bout first (r=-526, p = .046), and unrelated in those completing this bout second (r =-.049, p=.867). Completing a peak graded exercise test allows individuals to experience a spectrum of intensities, but observations within these subsamples suggest that the duration spent at each intensity level may not be sufficient to inform subsequent self-selected sessions. It appears that through experiencing a second, moderate-intensity bout, individuals were then able to self-select more pleasurable intensities in the final bout.

While these finding oppose a previous study (48) – wherein participants self-selected higher intensities when this bout was performed after an imposed bout – both studies highlight a potential problem with counterbalancing order of visits and the need for additional familiarization sessions when assessing behavioral outcomes. Perhaps more interestingly is that, in those who completed the self-selected bout first, individuals with lower energy scores appear to have chosen relatively higher intensity bouts. To date, we can only speculate the underlying causes, but inexperience is likely to play a role. One of the most commonly reported benefits of acute exercise is that it purportedly increases energy levels, which has been empirically supported by a recent meta-analysis (34). It is possible that this message has been internalized, such that participants in the current study aimed to use exercise as a means of feeling more energized. However, an alternative possibility is that participants did not conduct any self-assessments in order to inform exercise decisions. Additionally, the researchers did not provide or interpret EI scores to participants and utilized a neutral prompt for self-selected exercise. Combined with their relative inexperience with treadmill exercise, these issues may have led them to choose inappropriate workloads. Given the lower mean FS scores, we surmise that the latter possibility is more likely. In order to effectively implement FNLP-based practices in untrained adults, it may be necessary to teach individuals how to assess and interpret physical/mental readiness to exercise and explicitly prompt them to choose workloads that match their acute state. For a more in depth understanding of this phenomenon, future studies utilizing self-selected bouts would benefit from conducting qualitative assessments to determine factors involved in the behavioral choices of participants and test the impact of various prompting techniques. Such exploratory approaches are necessary to inform subsequent hypothesis-driven research in this area.

The current study is not without limitations. First, results are likely not generalizable across various other populations, aerobic exercise modes, or indices of volitional effort. Second, prior research has indicated that affective responses are most variable between individuals when exercising near ventilatory threshold (VT) (13). Because the current study did not assess VT, it is unclear whether EI can predict affective responses when intensity is set below, at, or above this physiological marker. Although setting aerobic intensity based on age-predicted HR_{max} has some inherent limitations (21), this approach is the most feasible for prescribing exercise intensity when true maximal (or VT) values are unknown. Third, although the POMS has been widely used in athletic populations (31, 47), it has received criticism, in that it was developed for use in clinical populations, is skewed toward negative mood states, and may lack sensitivity in detecting fluctuations in affective or mood states (4, 18). Thus, an important focus of future research is to operationally define exercise readiness and create validated measures of this construct.

While energy level as measured by the EI was predictive of affective responses to moderate-intensity aerobic exercise, hypotheses were not supported regarding self-selected intensity. Nonetheless, this research represents an important step in optimizing FNLP practices for aerobic exercise. Overall, adapting and implementing FNLP-based aerobic exercise prescriptions holds substantial promise as a means of promoting a more individualized, responsive program for untrained adults to improve long-term adherence. Such individualization is strongly promoted by the American College of Sports Medicine (21). Future research is necessary to build empirical support for this model. Additionally, the variability noted in EI, FS, and self-selected exercise intensity suggests that individuals, even those within a relatively homogeneous group in a controlled laboratory environment, do not respond uniformly to a given exercise prescription. These findings lend some support for the need to implement participant-responsive exercise prescriptions, as outlined in the FNLP framework.

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