Acceptance and Commitment Therapy Improves Exercise Tolerance in Sedentary Women

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Acceptance and Commitment Therapy Improves Exercise Tolerance in Sedentary Women

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ABSTRACT

IVANOVA, E., D. JENSEN, J. CASSOFF, F. GU, and B. KNÄUPER. Acceptance and Commitment Therapy Improves Exercise Tolerance in Sedentary Women. *Med. Sci. Sports Exerc.*, Vol. 47, No. 6, pp. 1251–1258, 2015. **Purpose**: To test the efficacy of an acute intervention derived from acceptance and commitment therapy (ACT) for increasing high-intensity constant work rate (CWR) cycle exercise tolerance in a group of low-active women age 18–45 yr. The secondary goals were to examine whether ACT would reduce perceived effort and improve in-task affect during exercise and increase postexercise enjoyment. **Methods**: In a randomized controlled trial, 39 women were randomized to either the experimental (using ACT-based cognitive techniques and listening to music during the CWR exercise tests) or a control group (listening to music during the CWR exercise tests). Before (CWR-1) and after the intervention (CWR-2), participants completed a CWR cycle exercise test at 80% of maximal incremental work rate (W_{max}) until volitional exhaustion. **Results**: On average, ACT (n = 18) and control (n = 21) groups were matched for age, body mass index, weekly leisure activity scores, and W_{max} (all $P > 0.05$). Exercise tolerance time (ETT) increased by 15% from CWR-1 to CWR-2 for the ACT group (392.05 ± 146.4 vs 459.39 ± 209.3 s; mean ± SD) and decreased by 8% (384.71 ± 120.1 vs 353.86 ± 127.9 s) for the control group ($P = 0.008$). RPE were lower (e.g., by 1.5 Borg 6–20 scale units at 55% of ETT, $P \leq 0.01$) during CWR-2 in the ACT versus that in the control group. By contrast, ACT had no effect on in-task affect. Exercise enjoyment was higher after CWR-2 in the ACT group versus that in the control group ($P < 0.001$). **Conclusions**: An acute ACT intervention increased high-intensity ETT and postexercise enjoyment and reduced perceived effort in low-active women. Further investigations of ACT as an effective intervention for enhancing the established health benefits of high-intensity exercise need to be provided. **Key Words:** ACCEPTANCE AND COMMITMENT THERAPY, EXERCISE TOLERANCE, RPE, EXERCISE ENJOYMENT

Physical inactivity is an independent risk factor for increased cardiometabolic morbidity and mortality (30). Nevertheless, only 3.2% of women in North America meet the recommended physical activity guidelines (46). High-intensity exercise offers comparable or superior health benefits (e.g., improved cardiorespiratory fitness) as low- or moderate-intensity exercise in both clinical and healthy populations (16). In fact, patients with cardiac diseases gain equivalent health benefits after a 12-wk low-volume, high-intensity intervention (10 × 1-min cycling intervals at ~90% of maximal work rate [W_{max}]) compared to a less time-efficient moderate-intensity intervention (30 min of continuous cycling at ~60% W_{max}) (9). In addition to time efficiency, recent research showed that 10 wk of high-intensity exercise training was associated with a 2.3-fold greater improvement (+17.9% vs 7.9%) in $\dot{V}O_{2peak}$ among patients with coronary artery disease than 10 wk of training at moderate intensities (40).

Theoretical and empirical research, however, suggests that participation in high-intensity activities may be undermined by perception of effort (as measured by RPE) (5) and negative affect (as measured by pain ratings or the Feeling Scale [FS]) (20), particularly among women (33,41). The psychobiological model of endurance performance (37), based on the motivational intensity theory (7), suggests that exercise tolerance is based on the perception of effort (i.e., how hard, heavy, and strenuous exercise is being perceived) (36) and on potential motivation (i.e., the maximum effort an individual is willing to exert). Consequently, factors that can target either or both components of the model may have the potential to increase exercise tolerance (e.g., Blanchfield et al. [4] and Marcora et al. [37]). In regards to affective responses to exercise, the Dual-Mode Model (DMM) (10), based on the hedonic theory of motivation (11), states that pleasant or unpleasant responses during exercise are determined by the

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interaction of cognitive factors (e.g., self-efficacy) and interoceptive feedback (e.g., physical discomfort) during exercise. The exercise intensity influences the relative salience of each factor in regulating the exercise-related affective responses (10). Primarily, an increase in exercise intensity (e.g., above the ventilatory threshold) is accompanied by a decline in effect for most individuals because the interoceptive cues stimulated by the exercise become more salient (10). Consequently, to effectively manage the demands of exercising, optimal techniques that improve affective responses to exercise and reduce perceived effort need to be identified, with the aim to sustain exercise tolerance at intensities that confer health benefits (e.g., Rognmo et al. [40]). Research efforts have so far focused on the use of diverting attention/distraction (e.g., listening to music) and association techniques (e.g., self-talk with a focus on the exercise experience), with some evidence that distraction techniques can have positive effects on RPE and in-task effect at low and moderate intensities (e.g., 60% and 75% of maximal HR) (6), whereas association techniques may decrease perceived effort at higher intensities (e.g., 80% of maximal work rate) (4). As the exercise intensity increases (e.g., 90% $\dot{V}O_{2max}$) (45), distraction techniques such as music become less effective at reducing perceived effort and maintaining exercise tolerance. Indeed, a comprehensive review of the literature showed that music has limited effects on reducing perceived effort during exercise at intensities above the anaerobic threshold (29). According to the effort-related model (44), sustaining attention on an external stimulus like music becomes effortful during high-intensity workloads owing to difficulties with diverting attention away from interoceptive (sensory) feedback. It follows that alternative cognitive strategies to distraction are required to help individuals better cope with the perceived effort during strenuous exercise. An important study by Blanchfield et al. (4) recently found that 12 recreationally active ($\dot{V}O_{2peak}$ ~53 mL·kg^{-1}·min^{-1}) men and women randomly assigned to a 2-wk motivational self-talk (i.e., an associative technique) intervention reported greater mean improvements in perceived effort and exercise duration during high-intensity constant work rate (CWR) cycle exercise testing at 80% of maximal work rate (W_{max}) than a group of 12 age-, sex-, and $\dot{V}O_{2peak}$-matched adults randomly assigned to usual exercise without self-talk intervention control group. It remains to be determined, however, whether similar improvements in perceived effort at high-intensity exercise performance can be achieved through an acute (single-session) application of cognitive techniques in physically inactive women, namely, women who are most in need of such improvements (e.g., Schaeffer et al. [41]).

Acceptance and commitment therapy (ACT) is a form of psychotherapy (21) that is widely used in clinical settings for the treatment and management of psychological disorders, and more recently, it has been applied to health-related behaviors, including cigarette smoking cessation (17), self-management of diabetes (19), and weight loss (15). One of the core assumptions in ACT is that negative and unpleasant feelings and experiences are neither good nor bad, but rather a facet of human life (21). Thus, acceptance-based techniques focus on increasing an individuals' willingness to experience aversive feelings, thoughts, and sensations, without trying to change or eliminate them (8,34). We proposed that acceptance-based techniques can help to improve affective responses, reduce perceived effort, and increase exercise tolerance during a high-intensity exercise test because ACT teaches individuals how to accept and defuse from the unpleasant internal experiences (e.g., exercise-related pain), in turn, for a behavior that they value (i.e., physical activity). Empirical evidence provides convincing support for the use of cognitive techniques derived from ACT (22) rather than suppression or distraction techniques (e.g., Masedo and Esteve [38]) in helping individuals to tolerate physical discomfort and pain. For example, a study of 219 young adults by Masedo and Esteve (38) randomized to the ACT intervention group were ~60% and 20% more tolerant to the pain and distress associated with the cold pressor test than individuals randomized to the suppression and spontaneous coping intervention groups, respectively. In light of these findings, the general aim of our theoretically grounded and randomized study was to examine the potential benefits of two cognitive techniques derived from ACT on exercise tolerance time (ETT) during a high-intensity cycle exercise test in apparently healthy, young, and low-active women. Our primary aim, therefore, was to test the hypothesis that a single session of ACT training will improve high-intensity (80% W_{max}) CWR cycle ETT in these women. The secondary aims were to examine whether these improvements in ETT are accompanied by improvements in perceived effort, in-task affect, and postexercise enjoyment.

METHODS

Participants

Thirty-nine nonsmoking, low-active, and nonpregnant or nursing women age 18–45 yr (23 ± 5 yr; mean ± SD) with no known or suspected cardiometabolic, pulmonary, and/or musculoskeletal disorder(s) and not taking psychotropic medications took part in this study.

Experimental Design, Randomization, and Procedures

As illustrated in Figure 1, this was a single-center, pretest–posttest, parallel-group, randomized controlled trial. The study protocol received ethical approval from the Institutional Review Board of the Faculty of Medicine at McGill University (IRB no. A00-B39-12B) in accordance with the Declaration of Helsinki.

After providing written informed consent, eligible individuals recruited by word of mouth and posted announcements in Montreal and the surrounding areas and participated in two testing visits separated by ≥48 h and completed within 1 wk.

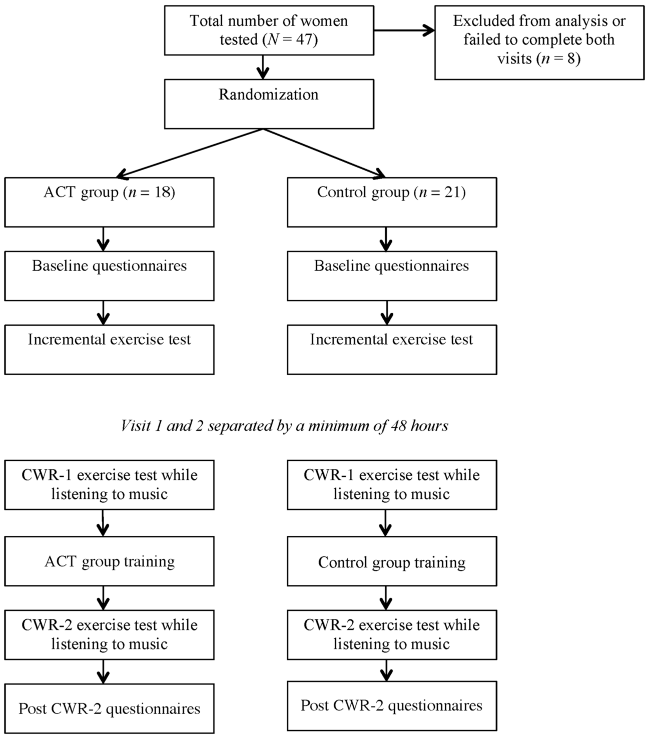

FIGURE 1—Flowchart diagram of the trial.

Participants were asked to avoid caffeine and/or energy drinks before testing and to not exercise 24 h before testing.

Visit 1 included the completion of baseline questionnaires followed by an exercise test until volitional exhaustion on an electronically braked cycle ergometer (Ergoline 800s; SensorMedics, Yorba Linda, CA) for familiarization purposes and for the determination of W_{max}. Incremental exercise tests consisted of a steady-rate resting period of 3 min followed by 25-W increases in work rate (starting at 25 W) to the point of volitional exhaustion: W_{max} was defined as the highest cycle work rate the participant was able to sustain for ≥30 s. The criterion for stopping the incremental exercise test was volitional exhaustion, which was assessed by 1) instructing the participants to give a clear indication (verbal or by waving their hand) that they have reached their absolute maximum effort and/or 2) by informing the participant that the test will be terminated if the pedal cadence falls below 50 revolutions per minute (rpm). Verbal encouragements were provided.

Visit 2 included two CWR cycle exercise tests at 80% W_{max} until volitional exhaustion: one before (CWR-1) and another after (CWR-2) the ACT or control intervention (see below). The time between the two CWR exercise tests was approximately 50 min (~40-min intervention and ~10-min preparatory and waiting period); refer to Figure 1 for a flowchart of the study design. High-intensity CWR cycle exercise tests to exhaustion were selected because they permit optimal control of workload and are as sensitive as cycle time-trial tests to detect changes in ETT (our primary outcome variable) in response to an intervention (1). The criterion for stopping the submaximal incremental exercise tests was volitional exhaustion, and the same instructions were provided to participants as during the incremental exercise test (Visit 1). Verbal encouragements were not provided. CWR exercise tests consisted of 1) a steady-rate resting period of 3 min, 2) a 1-min warm-up at 25% W_{max} while listening to music followed by a step increase in work rate to 80% W_{max} with participants cycling to volitional exhaustion while listening to music, and 3) a 3-min cool-down period. Participants provided ratings to the FS, the Felt Arousal Scale (FAS), and Borg's 6–20 category ratio scale of perceived effort at rest, within the last 15 s of every second minute during exercise and immediately after peak was reached. Similarly, participants were asked to identify whether they had an associative or distractive thought using the Association/Dissociation Scale within the first 15 s of every second minute during exercise and immediately after peak was reached. The scales presented during the exercise tests were shown in a fixed order. Immediately after the 3-min cool-down period, participants completed the FS, FAS, Physical Activity Enjoyment Scale (PACES), and responded to the manipulation check items, with all the scales presented in a fixed order. The manipulation check items included the following: 1) "How confident are you that you learned the acceptance-based techniques that we taught you?," with responses ranging from 1 (not at all confident) to 5 (very confident); and 2) "How frequently did you use the acceptance-based techniques during the last cycle exercise test?," with responses ranging from 1 (never) to 5 (all the time). ETT was defined as the duration of loaded pedaling.

Interventions

Online randomization software (www.randomization.com) was used to assign eligible participants to either of the two interventions upon arrival to the laboratory for testing. The research assistants conducting CWR-1 and CWR-2 exercise tests were blinded to the group allocation, whereas the ACT interventionist (E.I.) was not present during exercise testing at Visit 2.

ACT intervention. Participants randomized to the experimental group received a one-time ~40-min intervention (and additional ~10 min in preparatory/waiting period) in which they were taught cognitive defusion and acceptance techniques for coping with aversive physical discomfort (e.g., leg discomfort) and negative affect (e.g., boredom) during CWR-2. The intent of cognitive defusion was to help participants disentangle their physical sensations (e.g., burning legs) from their thoughts (e.g., "I must stop exercising") and behaviors (e.g., quit exercising). Acceptance techniques were used to help increase participants' willingness to experience consequences of a valued behavior (e.g., exercising) that may carry unpleasant physical sensations, without trying to change, control, or eliminate them (22). To illustrate both techniques, metaphors (adapted from Hayes et al. [21]) and an experiential exercise involving the use of an ice cube were utilized. The manual is available as a supplemental material online. [See table, Supplemental Digital Content 1, Acceptance-based techniques (defusion + acceptance), http://links.lww.com/MSS/A449.]

No-ACT intervention. Participants randomized to the no-ACT intervention control group watched a short video and created concrete goals for when, where, and how they would increase their overall physical activity levels upon study completion. Time spent with the interventionist (~40 min) and the preparatory and waiting period (~10 min) was matched to that of the ACT condition. After ~50 min, the participants completed CWR-2 and were asked to refer to the music as a means of coping with the high intensity.

Music Selection

During both CWR exercise tests, the participants listened to music (using headphones) that they selected according to their own preference from four genres: Pop, Hip-Hop and R&B, Electronic Dance, and Alternative Rock. Twelve songs from each of the aforementioned genres were selected from the *Billboard Canadian Hot 100* (2011–2013) and scanned using BeatScanner software: only songs with a tempo of 135–140 beats per minute (considered optimal for high-intensity exercise) (28) were included. Eligible songs were then purchased from Yes!Music Fitness, downloaded to iTunes, and synchronized to an Apple iPod Touch.

Measured Parameters

HR. This was monitored at rest and during exercise using a Polar HR monitor with chest band (Lachine, QC, Canada).

RPE. These were measured using Borg's 6–20 category ratio scale (5), where "6" represents "no exertion at all" and "20" represents "maximal exertion."

In-task affective responses. The circumplex model guided the selection of measures used to repeatedly assess affect during the CWR exercise tests. Specifically, affect can be defined by two dimensions: 1) affective valence (pleasure–displeasure) assessed by the FS (20), with responses ranging from −5 (very bad) to +5 (very good); and 2) perceived activation (low-high) assessed using the FAS (42), with responses ranging from 1 (low arousal) to 6 (high arousal). Both the FS and FAS are single-item measures that can be repeatedly administrated over a short period. The FS demonstrates strong concurrent and discriminant validity (12,42).

Attentional focus. The Association/Dissociation Scale (43) is a 10-point bipolar scale, with 1 representing association (e.g., thoughts related to the exercise) and 10 representing dissociation (e.g., distraction-related thoughts). This scale has established concurrent validity (3).

Physical activity enjoyment scale. The PACES (31), an 18-item measure incorporating a 7-point Likert scale (e.g., 1 [It is very pleasant or I dislike it] to 7 [It is no fun at all or I like it]), was administered immediately after the cool-down period of CWR-1 and CWR-2. The PACES has good predictive and discriminant validity (31).

Statistical Analysis

All statistical analyses were implemented by SAS 9.3, and power analysis was conducted using G*Power 3 (13). On the basis of past findings on the effectiveness of ACT techniques on promoting physical activity adherence (8), we determined *a priori* that ≥36 individuals (≥18 per group) were required to detect a moderate effect size of $\eta^2 = 0.15$ on our primary outcome variable (ETT) with α and power set at 0.05 and 0.80, respectively. The ETT variables were positively skewed, and natural log transformations were applied to the original variables before the main analysis (14). Owing to the variability in ETT for each participant, in-task affect (FS), activation (FAS), RPE, and association/dissociation were generated through linear interpolations between obtained adjacent values and anchored at baseline, 20% of ETT, 40% of ETT, 55% of ETT, and at peak exercise.

Baseline characteristics between the groups were compared using independent-sample *t*-tests and analyzed only for the participants who completed all testing sessions. Mixed-effect model was estimated using PROC MIXED, and contrasts were specified in the model to compare ETT from CWR-1 and CWR-2 both within and between groups and to test the associations between the groups (ACT vs control) and the repeated measurements during CWR-2 (RPE, FS, FAS, association/dissociation) and immediately after the CWR-2 (FS, FAS, and PACES). Owing to the technical difficulties in data collection, some outcome variables contained missing values, which were accommodated for by using the full information maximum likelihood estimator in PROC MIXED. An advantage of using the full information maximum likelihood estimator is that the observation in which the outcome variable is missing can be used in parameter estimation. Otherwise, in conventional repeated-measures ANOVA, the observation would be deleted. Also, the mixed-effect model gives the flexibility of specifying a patterned covariance structure for model residuals. In this study, we specified a first-order autoregressive AR(1) structure in PROC MIXED for residuals. The AR(1) structure is appropriate for data collected from repeated measures designs (27).

RESULTS

Forty-seven participants were recruited. Of these, seven participants failed to complete all testing sessions (e.g., because of dizziness) and were excluded from data analysis. One participant was excluded because she reported engaging in regular physical activity for >6 months before study participation. Thirty-nine participants were thus included in the analyses (Fig. 1): ACT (n = 18) versus control (n = 21). These participants had an average weekly leisure activity score (Godin-Leisure Time Exercise Questionnaire) of 13 ± 12 units, indicating that they were insufficiently active, with 24 units or more reflecting sufficiently active (18). The majority of the participants identified as East Asian (44.7%) and white (39.5%), with the remaining participants identified as

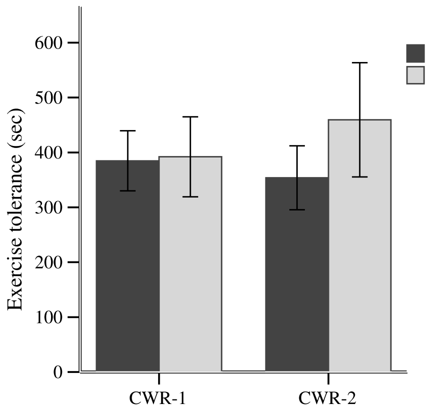

FIGURE 2—Exercise tolerance time means ± SEM for the control and ACT condition at CWR-1 (preintervention 80% W_{max} exercise test) and CWR-2 (postintervention 80% W_{max} exercise test).

South Asian (13.2%), African (2.6%), Aboriginal (2.6%), Biracial (5.3%), or Middle Eastern (5.3%). Body mass index (BMI), W_{max}, peak incremental cycle HR (HR_{peak}), and peak incremental cycle RPE for all 39 participants were 21.7 ± 4.1 kg·m^{-2} (range = 14.8–39.7 kg·m^{-2}), 130 ± 30 W (82% ± 16% predicted; range = 49%–119%; [2]), 179 ± 15 beats per minute (96% ± 7% predicted; range = 68%–109%), and 18.0 ± 1.5 (range = 14–20) Borg 6–20 scale units, respectively. These findings suggest that, on average, our participants were normal weight, low-active, and that they gave a maximal/near-maximal effort during exercise at Visit 1. The ACT and control groups were well matched for age (24 ± 6 vs 22 ± 5 yr), BMI (22.6 ± 5.4 vs 20.9 ± 2.4 kg·m^{-2}), average weekly leisure activity scores (11 ± 12 vs 15 ± 12 units), W_{max} (83% ± 18% vs 81% ± 15% predicted), HR_{peak} (94% ± 9% vs 97% ± 5% predicted), cycle work rate at 80% W_{max} (100 ± 23 vs 108 ± 25 W), and HR responses to CWR-1 and CWR-2 (all $P > 0.05$).

Manipulation check for the ACT group. Participants understood the ACT-based techniques and used them frequently during CWR-2: 83% of the ACT group reported feeling "confident" or "very confident" that they learned the ACT techniques. When asked if they frequently applied the techniques during the CWR-2 exercise test, 88.9% endorsed options 4 (no verbal anchor) and 5 (representing "all the time") on the 5-point Likert scale.

ETT. As hypothesized, a significant group–time interaction was observed for ETT: $F_{1,39} = 7.81$, $P = 0.008$, pseudo $R^2 = 0.05$ (see Fig. 2). The ETT at CWR-1 was 392.05 ± 146.4 and 384.71 ± 120.1 s for the ACT and control groups, respectively ($P = 0.98$). After the intervention, ETT was higher for the ACT group (459.39 ± 209.3 s) than for the control group (353.86 ± 127.9 s): *post hoc* planned contrasts indicated that ETT increased by 15% from CWR-1 to CWR-2 for the ACT group ($F_{1,39} = 4.94$, $P = 0.03$) and decreased by 8% for the control group ($P = 0.09$).

RPE. As expected, a significant group–time interaction was observed for RPE: $F_{4,148} = 5.92$, $P = 0.0002$, pseudo $R^2 = 0.81$ (see Fig. 3). Planned contrasts revealed a significant difference in Borg 6–20 scale RPE values between the ACT and control group at 40% (12.4 ± 2.8 vs 14.2 ± 2.2 units; $F_{1,148} = 9.81$, $P = 0.002$) and 55% (14.0 ± 2.8 and 15.4 ± 2.3 Borg 6–20 scale units; $F_{1,148} = 6.70$, $P = 0.01$) of ETT.

Attentional focus, in-task affect, and exercise enjoyment. Contrary to our expectations, a group–time interaction for in-task affect ($F_{5,185} = 1.01$, $P = 0.41$) or activation levels during CWR-2 and after immediately post cool-down ($F_{5,185} = 1.42$, $P = 0.22$) were not observed. By contrast, a significant group–time interaction was observed for perceived exercise-related enjoyment ($F_{1,31} = 21.61$, $P <$ 0.0001, pseudo $R^2 = 0.172$): pairwise comparisons showed no significant change in exercise enjoyment post CWR-1 ($P =$ 0.68), whereas exercise enjoyment after CWR-2 was significantly higher in the ACT group versus that in the control group (95.6 ± 13.7 vs 78.6 ± 18.9 arbitrary units; $F_{1,31} = 8.06$, $P = 0.008$). The exercise enjoyment scale further demonstrated high internal consistency: Cronbach α was 0.90 and 0.96 for CWR-1 and CWR-2 exercise tests, respectively. Lastly, a group–time interaction was not observed for attentional allocation during CWR-2 ($F_{4,148} = 0.77$, $P = 0.55$).

DISCUSSION

To our knowledge, this is the first randomized controlled study to show that an acute ACT intervention improved high-intensity cycle ETT by ~15% in apparently healthy, young, normal-weight, and low-active women. In keeping with the psychobiological model of endurance (37), the present study further showed that ACT-induced improvements in ETT were associated with improvements in perceived effort and ratings of postexercise enjoyment. Furthermore, our findings complement the results of a randomized trial by Blanchfield et al. (4) who recently showed that a 2-wk motivational self-talk intervention improved both ETT and perceived effort during CWR cycle exercise testing at 80% W_{max} in healthy, young recreationally active men and women. In addition, although DMM based on hedonic theory of exercise motivation (10) provides an important understanding of the mechanisms associated with affective responses during exercise, these findings demonstrate that DMM cannot

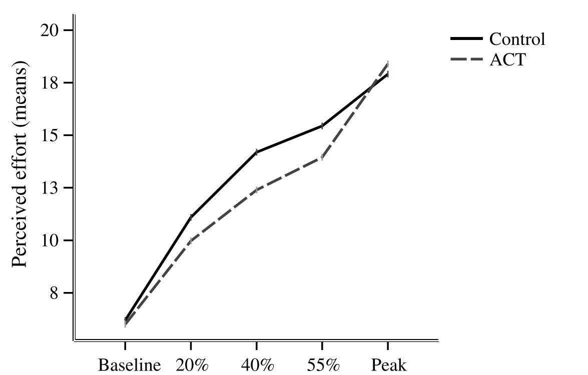

FIGURE 3—Mean RPE at baseline, 20%, 40%, and 55% of exercise tolerance and peak (100%) for the control and ACT condition during CWR-2 (postintervention 80% W_{max} exercsie test).

APPLIED SCIENCES

fully predict exercise tolerance among low-active individuals. The differential effect of affect and perceived effort on exercise behavior is elucidated by the fact that different theoretical and neurobiological mechanisms influence perceived effort and affective responses. Specifically, based on DMM, affective responses are influenced by afferent feedback from sensory receptors (e.g., chemoreceptors) that reach the affective centers of the brain (e.g., amygdala) (10), whereas perception of effort is generated by corollary discharges from motor to sensory areas of the cerebral cortex (35). The role of ACT in influencing the neurobiological signals associated with perceived effort remains to be determined by using neurophysiological methods and study designs. Moreover, future research needs to establish the long-term effect of these findings in relation to improving exercise adoption, maintenance, and, ultimately, health outcomes. The psychobiological model of exercise (37) based on the motivational intensity theory (7) can be used to guide this research. On the basis of the model, hypotheses can be generated with regard to how perception of effort may affect exercise-related decisions, for instance whether to engage or not with exercise, or when to disengage during exercise (i.e., volitional exhaustion).

An increase in high-intensity exercise tolerance among low-active women carries a twofold significance. First, a pervasive barrier to physical activity is lack of time (26), thereby prolonging exercise tolerance at high intensities may be a time-efficient alternative to low- and moderate-intensity activities with potentially important implications for adherence (32). Second, increasing exercise duration at high intensities (e.g., 80% W_{max}) may confer important health benefits including improvements in insulin sensitivity in sedentary, overweight, or obese adults (24) and in aerobic working capacity/cardiorespiratory fitness (e.g., $\dot{V}O_{2peak}$) and cardiometabolic risk factors (e.g., blood pressure) in healthy and clinical populations (9,16,23). Considering that ACT increased high-intensity exercise tolerance by ~15%, application of this simple psychological intervention with sedentary populations may be associated with vital improvements in health outcomes. Randomized, controlled, and longitudinal studies are necessary in this regard.

Another finding of the present study that may carry important implications for health and adherence was that the use of ACT techniques reduced perceived effort at an intensity of exercise at which distractive techniques (e.g., music) have previously been shown to become less effective in reducing perceived effort (29). It is noteworthy that, contrary to our expectations, the ACT techniques did not improve in-task affect, which is in support of the DMM, stating that affect is predominantly unpleasant during exercise above the ventilatory threshold (10). Whether or not ACT techniques such as those used in our study are capable of improving in-task affect during exercise at lower intensities (e.g., 50% W_{max}) requires further investigation.

The *mechanism* explaining the observed changes in perceived effort using ACT techniques remains less clear. The finding that perception of effort was reduced after the ACT training may be explained by motivational intensity theory (7,49), which postulates that actual effort is withheld for difficult tasks because "… effort requirements exceed what the performer is *capable* of doing" (49, p. 686). Hence, the individual discontinues effort because it is perceived as ineffective, as opposed to because the individual is not *willing* to engage in the behavior (49). The ACT techniques thus may have reduced perception of effort indirectly through increasing the perceived ability to perform the high-intensity exercise task (4). This hypothesized cognitive mechanism, however, needs to be examined in future research investigations. Differences in attention allocation cannot account for the perception of effort because both groups were associating (focusing on the physical sensations) throughout the exercise session, as opposed to distracting. This supports the Effort-Related Model, which states that association predominates at high intensities (44). This model further suggests that both association and diverting attention may reduce perceived effort at low and moderate intensities but not at high intensities. In contrast, research on individual differences in attention allocation shows that individuals whose dominant attentional style is association report lower perceived effort at high intensities than individuals whose dominant attentional style is dissociation (e.g., 85% of HR reserve) (25). To address the inconsistent findings on the efficacy of association during high-intensity exercise, future research needs to identify the cognitive mechanisms (e.g., active association with cognitive interpretations imposed on the physiological sensations vs passive association of monitoring body sensations) that lead to the effectiveness of association techniques. ACT techniques may be one possible cognitive mechanism with implications for enhancing association during high-intensity exercise. Lastly, the present study results also suggest that use of ACT techniques may improve postexercise enjoyment, even in the absence of variations in music and exercise setting (i.e., external factors that may affect enjoyment), which may have important implications for physical activity adoption and adherence (48). Future research efforts are required to further understand the relation between perceived effort and postexercise enjoyment and their relationship to exercise adherence.

METHODOLOGICAL CONSIDERATIONS

The CWR exercise tests until volitional exhaustion were completed before and after intervention on the same day, which had the potential to undermine the effect of the ACT intervention on measured parameters by exacerbating perceived effort and decreasing enjoyment and exercise tolerance during CWR-2 versus CWR-1 in this sample of low-active women. Therefore, the same-day testing may have undermined the ~15% increase in ETT and the RPE. Nevertheless, women randomly assigned to the ACT intervention demonstrated significantly greater mean improvements in ETT, perceived effort, and exercise enjoyment from CWR-1 to CWR-2 than those women randomized to the no-ACT intervention control group. Furthermore, although the exercise test used in this study is not relevant to the current exercise guidelines (47), an improvement in exercise tolerance at high intensities can help individuals with high-intensity interval training, which can be a time-efficient alternative to exercising at lower intensity levels for longer, and it is associated with equivalent health improvements (e.g., Gibala et al. [16]).

Women were characterized as "low active" based on their responses to the Godin-Leisure Time Questionnaire (18) without the use of objective assessment (e.g., accelerometers). Nevertheless, the Godin-Leisure Time Questionnaire has previously been shown to be significantly related to objective measures (e.g., CalTrac accelerometer) of physical activity (r = 0.45, $P < 0.01$) assessed during a 1-wk period (39). Furthermore, mean values of W_{max} were 82% of the age-, sex-, and height-predicted normal values (n = 39), thus supporting our participants' self-report of being low active.

Music is widely used by exercisers for its real and/or perceived psychological benefits (e.g., affect, motivation). It follows that our use of music during preintervention and postintervention CWR exercise tests increased the ecological validity of our study and its findings. The generalizability of our findings may be limited to apparently healthy, young, and low-active women. Furthermore, our intervention was acute (single-session) and we cannot comment on the potential benefits of repeated ACT interventions on measures of high-intensity exercise performance. Thus, future research should examine the potential performance-enhancing effects of short- and long-term ACT interventions in various other healthy (e.g., elderly, endurance-trained athletes) and clinical samples of men and women. Moreover, future research needs to establish whether it was the acceptance, cognitive defusion, or a combination of both ACT techniques that was the active ingredient in the reduction in perception of effort found in the present study.

CONCLUSIONS

In summary, the novel results from this randomized controlled study suggest that psychological techniques derived from ACT can be used in *combination* with music to help low-active women to perform high-intensity exercise for longer while also feeling less perceived effort and experiencing more enjoyment. Ultimately, the observed reduction in perception of effort and behavioral benefits derived from the ACT intervention, if sustained, may be associated with improved physical activity adoption and adherence with attendant health benefits. In this regard, the theoretically grounded findings of our study provide a rationale for further investigation of short- and long-term ACT interventions to enhance the established health benefits of high-intensity exercise training in both health and disease.

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The authors declare that there are no conflicts of interest.

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