Affective Responses to Exercise are Dependent on Intensity rather than Total Work

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ABSTRACT

KILPATRICK, M., R. KRAEMER, J. BARTHOLOMEW, E. ACEVEDO, and D. JARREAU. Affective Responses to Exercise are Dependent on Intensity rather than Total Work. Med. Sci. Sports Exerc., Vol. 39, No. 8, pp. 1417-1422, 2007. Purpose: The purpose of the study was to compare affective responses for two bouts of cycle ergometry with differing duration and intensity, but equal total work in kilocalories. Methods: Thirty-seven participants (20 male, 17 female, mean age 23.9 yr) completed a multistage cycle ergometer protocol to determine ventilatory threshold (VT) and peak oxygen consumption (mean = 34.9 mL·kg⁻¹·min⁻¹). Two cycling trials were prescribed: 30 min at 85% of VT (50.1% VO₂ reserve) and an average of 24 min at 105% of VT (64.7% VO₂ reserve). The length of the 105% of VT bout was adjusted to yield equal total work in each exercise trial. Results: Using repeated-measures ANOVA, heart rate and exertion were significantly higher, and affective valence was significantly less positive (P < 0.01) for the higher-intensity, shorter-duration bout, with no differences in felt arousal (P > 0.05). Additionally, affective valence became less positive during the higher-intensity bout (P < 0.01) but not the lower-intensity bout (P > 0.05). Conclusion: These data extend previous findings by showing that the decline in ratings of pleasure during higher-intensity exercise is not dependent on differences in total caloric expenditure. Additionally, results from this study support continued promotion of prescriptions that focus on exercise intensity that does not exceed the VT. Key Words: AFFECT, VALENCE, AROUSAL, EXERTION

Given the clear health and fitness benefits of aerobic exercise, one would expect that regular exercise participation would be the norm. However, epidemiological data indicate that most American adults do not meet recommended levels of exercise participation. Specifically, 23% of American adults participate in light to moderate physical activity five or more times each week, and 15% of Americans participate in vigorous physical activity three or more times per week (24). These rates are far below the 30% target figures set forth for each physical activity level in current recommendations for Americans (24), and they represent a public health problem of great significance with respect to physical activity behavior.

Currently, two rather distinct sets of recommendations are made available to the public from the American College of Sports Medicine (ACSM), the U.S. Centers for Disease Control and Prevention, and the Office of the Surgeon General (2,3,19,23). The earliest recommendations developed by ACSM were based on the assumption that more intense exercise and associated fitness improvements were prerequisites for health (2,3). In contrast, contemporary public health-oriented recommendations based on public health objectives recognize the value of physical activity that improves health status without significant fitness increases (19,23). These contemporary public health-oriented recommendations reflect a lowered minimum intensity (from 50 to 40% of maximal oxygen uptake reserve), increased exercise frequency (from 3–5 to 5–7 d·wk⁻¹), and more flexibility in the achievement of exercise duration (from continuous to an accumulation of intermittent activity) compared with the original fitness-oriented guidelines. Thus, although the total caloric expenditure of the original and the more recent recommendations remain largely unchanged, the means for achieving the expenditure has evolved from a model based on cardiorespiratory fitness to one that is more intimately connected to general health promotion. This more contemporary view reflects a trend to embrace the health and fitness benefits of low- and moderate-intensity physical activity.
activity such as walking and adopt the intuitive position that less vigorous physical activity programs are more likely to result in improved adherence. At least two studies have reported that lower-intensity aerobic training programs result in enhanced behavioral maintenance (17,20), but the specific mechanism to explain the differences between conditions has not been investigated.

One possibility is that lower-intensity exercise is associated with more positive affective states during and after exercise than in high-intensity exercise. Several studies have compared affective responses to multiple bouts of aerobic exercise that varied in intensity (1,6,15,18). These studies consistently found that higher intensities are associated with less favorable affective responses. This pattern of effects has been described in the dual-mode theory (13). This theory argues that lower-intensity exercise is associated with largely homogeneous, positive affective responses. In contrast, affective responses are variable in response to exercise near the ventilatory threshold (VT) and become uniformly negative at intensities well beyond VT. This may be explained by an increase in afferent stimulation (i.e., increased anaerobiosis, muscle discomfort) that is proportional to the exercise intensity (13). As intensity exceeds VT, the substantial increase in afferent stimulation reaches a level that may limit the impact of social–cognitive variables such as self-efficacy and motivation, leading to a unified, negative affective response.

The dual-mode theory of affect and exercise intensity provides a solid conceptual guide from which to base investigations of affective responses to aerobic exercise. However, the existing research has not adequately tested its basic predictions. Previous investigations have manipulated exercise intensity while holding duration constant. This clearly confounds exercise intensity and the total work completed. It may be that the observed difference in affective response is attributable in part to the greater overall exercise dose in the more strenuous exercise bout. This is particularly important, given the use of exercise prescriptions that differ in both intensity and duration to achieve the same caloric expenditure goal. To date, only one study has addressed the impact of total work with regard to postexercise affective states (7). The study determined and used VT in a manner that differs from the commonly accepted method used by most investigators. The study compared the affective responses to two bouts of cycle ergometer exercise. The first bout included 35 min of exercise at a VT defined as the lowest point of $V_{\text{E}}/V_{\text{O}_2}$ before systematic increase (termed VT1); the second bout involved 20 min of exercise at a higher VT (termed VT2) defined as the lowest point in the ratio of $V_{\text{E}}/V_{\text{CO}_2}$ before a systematic increase. The VT1 and VT2 intensities corresponded to approximately 50 and 70% $V_{\text{O}_2}\text{max}$, respectively. Results indicated that the two intensities produced similar levels of postexercise positive well-being and psychological distress, whereas the higher intensity produced greater levels of fatigue. Unfortunately, no study has controlled for total external work and measured affective states during exercise (i.e., in task) within the same design. This void in the literature is significant because any attempt to assess the affective consequences of exercise intensity should include assessments both during and after exercise (14).

The present experiment was designed to fill this void. The purpose of the study was to compare affective responses for two bouts of cycle ergometry with differing duration and intensity, but equal total external work. This design feature provides an opportunity to consider a question addressed by previous research without the confounding influence of variation in total work. Previous literature would suggest that trials of different intensity would result in different affective responses (1,6,15,18), but research to date has not yet addressed this issue while controlling for total work and assessing affect both in task and after exercise. By comparing the pattern of in-task affect with that of postexercise affect, this design will indicate if either a shorter or longer exercise duration is more sensitive to the effects of intensity despite similar workload. Additionally, this investigation provides for further testing of predictions from the dual-mode theory (13). It was expected that an above-VT trial would elicit less positive responses than a trial at an intensity below VT.

**METHOD**

**Participants and research design.** Participants were 37 unpaid undergraduate student volunteers (20 men, 17 women, mean age ± SD = 23.9 ± 4.66 yr) enrolled at a regional university in the southeastern United States. The size of the sample was based on a power analysis that considers the correlation among measures (10). The resulting procedure used a 2 (trial) × 6 (time) within-subject factorial design with repeated measures on both factors, with effect-size estimates based on previous work (1). Specifically, with effect size = 1.00, alpha = 0.05, and a moderate 0.5 correlation among data obtained at different time points, 37 participants resulted in a power of 0.84. As a result, the sample of 37 participants was sufficient to detect the expected difference between conditions. Participants were diverse in terms of fitness status and were recruited from exercise and health courses at the university. The participants completed three trials separated by at least 48 h. The first trial was a maximal protocol to measure both peak oxygen uptake ($V_{\text{O}_2}\text{peak}$) and VT. The second and third trials were submaximal and included a shorter bout at a higher intensity and a longer bout at a lower intensity. Duration of exercise was manipulated to ensure equal total external work for both trials. This study employed a randomized and counterbalanced design that allowed the different effects of the trials to be compared using the same participants for both exercise trials. The primary outcome measures of the study were affective valence and arousal; heart rate and perceived exertion served as manipulation checks.

**Screening.** Each participant completed an informed consent document, a demographic questionnaire, and a health status questionnaire. Participants classified as low risk for
exercise participation according to the ACSM guidelines (e.g., lipids, smoking status, family history, fasting glucose) were invited to complete the study (4). The sample was delimited in this manner because physician supervision was not readily available for maximal exercise testing. Participants were given instructions consistent with ACSM guidelines regarding the use of tobacco and the ingestion of food, alcohol, and caffeine as well as sleep and clothing considerations (e.g., avoid alcohol, caffeine, and tobacco for 3 h before testing) (4). Participants provided informed consent in accordance with institutional guidelines before the first exercise session. All documents and procedures were approved by the university institutional review board.

**Metabolic testing.** A progressive, multistage cycle ergometer protocol was used to determine VT and $\dot{V}O_2$peak. Each participant completed a 3-min unloaded warm-up on a calibrated Monark 828E cycle ergometer (Monark, Sweden). On completion of the warm-up period, participants engaged in a progressive protocol until volitional termination. The workload was adjusted upward each minute and the required pedal cadence was 60 rpm. Workload adjustments were based on gender, body mass, and reported level of physical activity (25). The range of adjustments made each minute for women was 10–20 W, compared with 20–30 W for men. Expired $O_2$ and $CO_2$ concentration were analyzed using a ParvoMedics TrueMax metabolic cart (ParvoMedics, Sandy, UT). $\dot{V}O_2$peak was identified as the largest amount of oxygen consumed per minute during the test. VT was identified by ParvoMedics TrueMax software using the $V$-slope procedure (5) and verified through visual inspection of ventilatory equivalents for $O_2$ and $CO_2$. Concurrence of visual VT determination by two of the study authors was used when initial visual and software estimates were in disagreement.

**Experimental exercise trials.** Data obtained from the graded exercise test allowed for the determination of the workload and oxygen consumption associated with VT. The workload in watts at VT was used to prescribe two trials of exercise on a calibrated Monark 828E cycle ergometer. Workload at VT was used as the basis of prescription rather than a percentage of oxygen consumption. The higher workload corresponded to 105% of VT (mean workload ± SD = 165.0 ± 43.2 W), and the lower workload corresponded to 85% of VT (mean workload ± SD = 132.2 ± 33.4 W). This manipulation of exercise intensity based on data from the graded exercise test resulted in a predicted oxygen consumption level classified as hard and moderate, respectively (hard: mean oxygen uptake ± SD = 64.7 ± 11.1 % $\dot{V}O_2$ reserve; moderate: mean oxygen uptake ± SD = 50.1 ± 8.8 % $\dot{V}O_2$ reserve) by the ACSM (4). The length of the moderate bout of exercise was set at 30 min for each participant (mean duration ± SD = 30.0 ± 0.0 min). Adjustments were then made to the length of the hard bout individually for each participant (mean duration ± SD = 24.2 ± 0.82 min) so that total work output in watts would be equal to the corresponding moderate bout. The result of these adjustments provided two trials of exercise that differed on both intensity and duration, but were equal in terms of total work: hard and shorter (HS) and moderate and longer (ML). Both trials included a warm-up and cool-down of 3 min. The first minute of each warm-up was conducted at no resistance, the second minute of each warm-up was conducted at one third of the prescribed resistance, and the final minute of warm-up was conducted at two thirds the prescribed resistance. The cool-down period prescriptions were identical to the warm-up prescriptions, but in reverse order. Each trial was separated by a minimum of 48 h and a maximum of 1 wk.

**Instrumentation.** Variables that were assessed included heart rate, perceived exertion, arousal, and affective valence. Heart rate (HR) was measured using a Polar heart rate monitor. Rating of perceived exertion (RPE) was measured with Borg’s CR-10 scale (8). Arousal was measured using the felt arousal scale (FAS) (22). The FAS is a single-item indicator of activation scored on a six-point scale (from 1: low arousal to 6: high arousal). Affective valence was measured using the feeling scale (FS) (16). The FS is a single-item indicator of affective valence scored on an 11-point scale (from −5: very bad to 5: very good). The FS and FAS allow for separate assessments of activation and affective valence. This approach is consistent with the circumplex model of affect, which conceptualizes affective state as the combination of these constructs (21). Such an approach has been recommended for use in the study of acute exercise because it provides the broad perspective needed to capture the diverse and multifaceted affective experiences associated with exercise (12). Therefore, because exercise may have an effect on activation that is separate from its effect on affective valence, the ability to separate these effects allows for a clearer interpretation of any in-task affective change.

Before the graded exercise test the participant read a thorough description of what each indicator was designed to measure. This step served as a familiarization trial for the perceptual and affective measures. RPE, FAS, and FS were assessed at the end of each segment of the constant-load exercise bout: 20, 40, 60, 80, and 100% of trial completion. This resulted in the time points for the ML trial occurring every 6 min (mean time ± SD = 6.0 ± 0.0 min) and approximately every 5 min for the HS trial (mean time ± SD = 4.8 ± 0.7 min). This was done so that data-collection points would occur at equal percentages of total work completed. Additionally, the FAS and FS were administered at three time points outside of the exercise trial: (i) immediately before exercise (pre), (ii) immediately after exercise cool-down (post-0), and (iii) 15 min after exercise (post-15). Each of these measurements was taken while the participant was seated comfortably in a reclining chair in an area adjacent to the exercise equipment.

**Statistical analysis.** Analyses of the data proceeded in three phases. The first phase included descriptive analysis of sample and graded exercise test characteristics. This phase also compared the HS and ML trials on work-related
characteristics of the exercise bout using dependent t-tests. Significant trial effects were hypothesized for each variable. The second phase used a 2 (trial: HS and ML) x 3 (time: pre, post-0, post-15) repeated-measures ANOVA on FS and FAS. In line with previous literature, a significant effect of time was predicted for FS and FAS, along with a significant effect of trial on FAS. The third phase used a 2 (trial: HS and ML) x 3 (time: pre, 20%, 40%, 60%, 80%, 100%) repeated-measures ANOVA on VO2 and FAS. Separate ANOVA were used for the in-task and the pre-post data in an attempt to discern whether either of these periods was more sensitive to the effects of exercise intensity. Additionally, because previous literature has not shown a consistent-intensity effect for affect during and affect after exercise, the pre-post comparisons were separated from the in-task comparisons. Whenever the assumption of sphericity was violated, the degrees of freedom were adjusted and reported using the Greenhouse–Geisser correction. Significant time x trial interactions were predicted for all variables and were decomposed into their simple effects of time within each trial. Significant simple effects of time were followed by planned contrasts in which each in-task and posttask assessment was compared with their pretask values. Because these comparisons increase the risk for type I error, the P value for post hoc analyses was adjusted according to the Bonferroni correction to 0.025 for pre to post comparisons and to 0.01 for pre to in-task comparisons.

RESULTS

Graded exercise testing. The participants were marginally overweight (mean body mass index ± SD = 25.2 ± 4.3 kg·m⁻² for males and 28.3 ± 4.1 kg·m⁻² for females) and below-average fitness for their age (\(\text{VO}_{2\text{peak}}\) = 37.3 ± 6.8 mL·kg⁻¹·min⁻¹ for males and 32.1 ± 8.0 mL·kg⁻¹·min⁻¹ for females) (4). Peak HR (mean HR peak ± SD = 178.4 ± 10.6 bpm) was below the criterion for maximal effort based on age (within 10 bpm of age-predicted maximum). This HR value was 7–8 bpm below the criterion and not unexpected because of the selected exercise modality, cycling. Peak respiratory exchange ratio (RER = 1.25 ± 0.09) was above the 1.15 criterion for maximal effort. Peak RPE (mean ± SD = 9.3 ± 1.8) was above the 9 criterion (0–10 scale) for maximal effort (4). Collectively, the instructions given to the participants and the data collected during the incremental cycle ergometer test suggests that exhaustion occurred and a \(\text{VO}_{2\text{peak}}\) was achieved. Additionally, metabolic gas analysis indicated that the VT (mean ± SD) occurred at 65.1 ± 9.7% of \(\text{VO}_{2\text{peak}}\).

Submaximal exercise trials. The analyses of work-related variables measured at the conclusion of the two exercise trials served primarily as a manipulation check for differences in intensity and duration (Table 1). Results from these dependent t-tests indicate that the two exercise trials differed on workload, perceived exertion, heart rate, duration, and oxygen consumption predicted by external workload (P < 0.001). In contrast, comparisons indicated that the trials were equal in terms of external work (determined by multiplying workload by exercise duration) and predicted caloric cost (determined by multiplying predicted oxygen consumption by exercise duration) (P > 0.05).

Responses before and after exercise. There were no differences in FS data: time F(1, 27.41) = 3.21, P > 0.05; trial F(1, 33) = 0.4, P > 0.05; and time by trial F(1, 50) = 0.00, with no significant effect for trial, F(1, 33) = 2.54, P > 0.05. A similar analysis was completed for FAS data, and there was a significant effect of time, F(1, 48, 50.39) = 8.73, P < 0.05; with no significant effect for trial. Since this was a repeated measures analysis, and there was a significant interaction between these factors, F(1, 48, 55.78) = 2.54, P > 0.05. As a result, the trials were collapsed for planned contrasts that compared each postexercise observation with the preexercise measure of FAS. These analyses revealed that FAS scores were significantly higher immediately after exercise (P < 0.025), with no difference between pre and 15 min after exercise for the two trials (P > 0.05). The FS and FAS data are provided in Figures 1 and 2, respectively.

Responses during exercise. For the FS data, there was a significant effect of time F(1.73, 41.91) = 9.44, P < 0.05, as well as a significant effect for trial, F(1, 36) = 10.81, P < 0.05. Additionally, there was a significant interaction between these factors, F(2.46, 88.60) = 1.16, P > 0.05 or interaction between these factors, F(1.64, 55.78) = 2.54, P > 0.05. As a result, the trials were collapsed for planned contrasts that compared each postexercise observation with the preexercise measure of FAS. These analyses revealed that FAS scores were significantly higher immediately after exercise (P < 0.025), with no difference between pre and 15 min after exercise for the two trials (P > 0.05). The FS and FAS data are provided in Figures 1 and 2, respectively.

RESPONSES DURING EXERCISE

FIGURE 1—Feeling scale responses to exercise. Data represent mean ± SE for feeling scale before, during, and after the hard and shorter (HS) and moderate and longer (ML) trials. * Significantly different from preexercise measure (P < 0.005) for HS trial only.
significant, $F(1.94, 69.83) = 2.06, P > 0.05$. In contrast, there was a significant effect of time for the HS trial, $F(1.89, 68.02) = 11.14, P < 0.05$. Planned contrasts on the HS data reveal that FS was significantly lower than the pretest at each in-task assessment ($P < 0.01$), with effect size ($d$) ranging from moderate to large (pre-20%; $d = 0.45$; pre-40%; $d = 0.78$; pre-60%; $d = 0.97$; pre-80%; $d = 0.99$; pre-100%; $d = 0.85$). These data are presented in Figure 1.

For the FAS data, there was a significant effect of time, $F(1.86, 66.96) = 10.65, P < 0.05$; with no effect for trial, $F(1.36) = 0.48, P > 0.05$ or the interaction between these factors $F(2.78, 97.80) = 0.93, P > 0.05$. As a result, trials were collapsed for planned contrasts that compared each in-task exercise observation with the preexercise measure of FAS. This analysis revealed significant increases in FAS (in comparison with preexercise values) at 40% ($d = 0.44$), 60% ($d = 0.60$), 80% ($d = 0.66$), and 100% ($d = 0.64$) assessments ($P < 0.01$), but not at 20% ($P > 0.05$). These data are presented in Figure 2.

DISCUSSION

This experiment was designed to investigate the affective responses before, during, and after cycle ergometer exercise trials that differed in intensity and duration but were equal in total work and caloric cost. The research design involved assigning participants to two bouts of exercise on separate days that were described as either moderate and longer (50% VO\textsubscript{2} reserve; 85% of VT; 30 min) or hard and shorter (65% VO\textsubscript{2} reserve; 105% of above VT; 24 min). The exercise protocols used in this study resulted in different exercise intensities and durations, but equal caloric cost. Specifically, the protocols resulted in different workloads (by more than 30 W), HR (by approximately 15 bpm), RPE (by approximately two categories), duration (by approximately 6 min), and estimated percentage of maximal oxygen uptake reserve (by approximately 15%), and they resulted in equal caloric expenditure (approximately 350 kcal) and levels of arousal as measured by the FAS. Thus, the protocol manipulation was successful.

The results of the current study support previous findings that exercise intensities above VT produce less favorable affective responses (1,6,15,18) and extends previous work by demonstrating that the effects of exercise intensity on affect are independent of total work completed. Specifically, although both trials resulted in similar increases in felt arousal, the high-intensity trial resulted in a significant decline in affective valence. This reduction began at the first assessment and continued until the completion of exercise. In contrast, there was no change in affective valence during exercise below VT. This result is particularly interesting as intensity had no effect on postexercise affect. Both trials resulted in similar changes in activation and affective valence immediately and 15 min after exercise. Thus, the effect of exercise intensity on affect during exercise seems to be largely unrelated to affect after exercise. These effects occurred despite varying the length of the trial to control for caloric expenditure. As a result, these data serve to extend existing research that has not differentiated the effects of exercise intensity and total work completed. This research also underscores the importance of assessing, and comparing, affective responses, both during and after exercise (6,11).

These findings have implications for exercise prescriptions that differ in intensity and duration to achieve a similar overall dose of work. There seems to be an assumption that lower-intensity, more frequent exercise bouts will be better tolerated by participants and, in turn, lead to greater rates of participation or lower risk of dropout. Although the link with adherence has yet to be fully explored, the present data indicate that below-VT bouts of exercise are associated with more positive affective states, even if they are of longer duration. As such, the results of the current study support the basic tenets of the dual-mode theory (13). Exercise above VT is generally perceived as aversive, whereas exercise at lower intensities is likely adaptive and pleasant. Higher intensities are thought to be perceived more negatively because of the significant disruption in homeostasis, which is believed to be maladaptive and not supportive of continued behavior (9). That is, intensities beyond the VT may well elicit more negative affective responses for the purposes of discouraging future participation in such strenuous activities in favor of more moderate intensities that are perceived more positively.

A primary limitation of this study relates to the sample. The current sample is rather narrow in terms of age, weight status, fitness status, and educational status. Such limitations in the sample prevent broad generalizations to the overall population, particularly to older and overweight population segments. However, the low-to-moderate fitness status of this sample mirrors large portions of the general U.S. population in terms of maximal aerobic power and, thus, serves to improve the ability to generalize to this segment.

Recommendations for future research include an examination of in-task and postexercise affective responses and exercise adherence. Although a relationship between affective responses to exercise and adherence is plausible, evidence remains limited and research to date has not
compared in-task and postexercise affect to patterns of adherence. Given the different effects of exercise intensity on in-task and postexercise affect found in the present study, further investigation is warranted. Such work should prove invaluable in efforts to develop exercise prescriptions that can maximize adherence to exercise programs. Likewise, there is a need to use more diverse samples and to vary experimental protocols. Similar research with older, less fit, and overweight populations could prove useful. The current project was conducted employing the upright cycle ergometer and future studies might consider other exercise modalities. Future work might also focus on a wider variety of exercise intensities both above and below VT. Intermittent bouts above and below VT would also be of interest, given the variable methods employed by individuals to accumulate recommended levels of physical activity.

In summary, the manipulation of exercise intensity and duration allowed for the creation of two distinct bouts of exercise resulting in equal work output. Findings from this experiment indicate that affective valence is reduced for higher-intensity exercise compared with moderate intensity at an equal total caloric expenditure, but activation was not impacted. We are aware of no other study that has examined the impact of exercise intensity on affective response both during and after aerobic exercise while controlling for total work. Such findings support growing sentiment that increased exercise intensities may negatively impact exercise adherence (17,20). Although the current project did not investigate maintenance of exercise behavior, it is possible that exercise adherence is undermined by the generally less positive affective responses that seem to occur at intensities above the VT.

REFERENCES
