Psychophysiological Responses to Self-Paced Treadmill and Overground Exercise

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[1]Department of Physical Education, Federal University of Parana, Curitiba, BRAZIL; [2]Department of Health Sciences, University of Rome "Foro Italico," Rome, ITALY; and [3]Department of Health and Physical Activity, University of Pittsburgh, Pittsburgh, PA

ABSTRACT

DASILVA, S. G., L. GUIDETTI, C. F. BUZZACHERA, H. M. ELSANGEDY, K. KRINSKI, W. DE CAMPOS, F. L. GOSS, and C. BALDARI. Psychophysiological Responses to Self-Paced Treadmill and Overground Exercise. *Med. Sci. Sports Exerc.*, Vol. 43, No. 6, pp. 00–00, 2011. Speculation exists that a positive affective response experienced during exercise may play an important role in predicting exercise adherence. Previous studies using self-paced exercise protocols have been associated with health benefits and pleasant experiences. However, all of these studies were conducted in laboratories, and consequently, the external validity of the findings may be questionable. **Purpose**: To determine whether environmental settings (treadmill vs overground) differentially influence physiological, perceptual, and affective responses to exercise at a self-selected pace. **Methods**: Thirty-four individuals (17 men and 17 women) between 18 and 30 yr volunteered to participate in this study. During the orientation session, individuals underwent an initial screening, anthropometric measurements, and familiarization with the experimental procedures. Next, subjects underwent a maximal treadmill test. In the two experimental trials, participants performed 20-min bouts of treadmill and overground walking at a self-selected pace, which were completed in a counterbalanced order. At least 48 h separated experimental trials. **Results**: Using repeated-measures ANOVA, overground walking speed was significantly faster than treadmill walking speed ($P < 0.01$) during the 20-min bout of self-paced exercise. However, exercise intensity (%$\dot{V}O_2$R and %HRR) and perceived exertion during the session of overground walking were significantly lower ($P < 0.05$) when compared with those during the treadmill session. In addition, affective valence was more positive during the session of overground walking than during the treadmill session ($P < 0.01$). **Conclusions**: These data extend previous findings by showing that environmental setting influences physiological, perceptual, and affective responses during exercise at a self-selected pace. Self-paced exercise performed over ground resulted in lower perceptual and more positive affective responses. **Key Words:** ADHERENCE, EXERCISE INTENSITY, SELF-REGULATION, BORG SCALE, AFFECT

It has been well documented since the 1950s that regular physical activity produces beneficial effects on health (23–25,28). Despite this fact, physical inactivity continues to be a major public health problem in many industrialized countries. According to the World Health Organization (42), about 1.9 million people worldwide die each year from diseases related to physical inactivity. In addition, about 19 million of disability-adjusted life years are lost annually because of physical inactivity. Although several public health strategies have been adopted to reduce the prevalence of physical inactivity, the proportion of people meeting the current recommendation of accumulating ≥30 min of moderate physical activity at least five times a week or ≥20 min of vigorous physical activity at least three times a week has remained essentially unchanged during the last two decades (42).

The low rate of adherence to physical activity programs has been considered an important contributing factor to physical inactivity (7,8). In fact, a meta-analysis conducted by Dishman and Buckworth (7) found that approximately 50% of individuals who initiate a physical activity program drop out within the first 6 months. Thus, many people withdraw from physical activity programs before physiological gains occur. According to Parfitt et al. (29), identifying the factors that contribute to nonadherence has been one of the greatest challenges for exercise researchers during the last few decades.

The prescription of vigorous-intensity activities has been recognized as a contributing factor to nonadherence to physical activity programs. Data from both epidemiological and intervention studies have shown that sedentary individuals are more likely to adhere to low-intensity activities than high-intensity activities (7,33,38). Indeed, in a longitudinal community survey, Sallis et al. (38) found that

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rates of adherence were considerably greater (65%–75%) for moderate-intensity activities compared with vigorous-intensity activities (50%). Similarly, a more recent randomized trial conducted by Perri et al. (33) found that recommending walking at a moderate as opposed to a higher intensity produced not only a better adherence to the physical activity program (66% vs 58%) but also a greater amount of exercise completed (85 vs 72 min·wk^{-1}). These studies support the idea that exercise intensity influences the adherence to physical activity programs. However, none of these investigations provided any additional information about the potential mediators of the relationship between exercise intensity and adherence.

Several recent studies have suggested that the relationship between exercise intensity and adherence to a physical activity program might be mediated by the amount of pleasure that an individual experiences during exercise (10,13,36,40). This hypothesis has been based on the fundamental assumptions of the so-called "hedonic" theory of motivation (18), which argues that, if people derive pleasure, sense of energy, or enjoyment from their physical activity participation, they would probably seek to repeat this activity. On the other hand, if people derive displeasure, sense of exhaustion, pain, or discomfort from their physical activity, the chances of them repeating the activity would be reduced. Thus, activities that lead to "feeling good" are more likely to facilitate adherence, whereas those that do not are more likely to lead to cessation of the activity (29). In fact, in a recent study, Williams et al. (40) showed that affective responses to a single bout of moderate-intensity activity were able to predict exercise participation up to 6 and 12 months later. On the other hand, this direct relationship between affective responses and future exercise participation became nonsignificant after controlling for perceived exertion. Therefore, it is likely that maximizing the positive affective response while minimizing perceived exertion may be an important strategy in enhancing adherence to physical activity programs.

The use of self-selected exercise intensity protocols has been advocated as a means of producing positive effects on affective and perceptual responses in sedentary individuals (6,10–12,21). Because the participants of an exercise program are not simply "passive" agents, using the individual's cognitive appraisal processes to choose an exercise intensity might contribute to improved affective and perceptual responses. However, according to the dual-mode model proposed by Ekkekakis et al. (11), to use these cognitive appraisal processes to produce positive affective responses the exercise intensity must be at or below the ventilatory threshold. Once exercise intensity is greater than this threshold, interoceptive cues gain salience and become the primary determinant of the affective responses. Moreover, the model of Ekkekakis et al. (11) also suggests that, during exercise performed at intensities below and at the ventilatory threshold, the effects of these cognitive appraisal processes, which are likely influenced by self-efficacy, goal achievement, social context, and personality variables, may contribute to increased interindividual variability in the affective responses to exercise. Interestingly, recent studies have found that individuals exercising at a self-selected pace tend to choose an intensity near the ventilatory threshold (6,13,21), and the interindividual variability in the affective responses is reduced (35).

Several studies have also revealed that most people are not only predisposed to select an exercise intensity that produces positive perceptual and affective responses but also able to choose a physiological stimulus adequate to promote health benefits (i.e., an exercise intensity between 55%/65% and 90% of HR_{max} or between 40%/50% and 85% of oxygen consumption reserve ($\dot{V}O_2R$) or HR reserve (HRR) 1) **AQ1** (6,13,21,29,30). These findings reinforce the observation that health benefits and pleasant experiences may be associated with self-paced exercise protocols. However, it should be noted that all of these studies were conducted in laboratories, and consequently, the external validity of the findings may be questionable. This is particularly important, given that the physiological, perceptual, and affective responses to self-paced exercise performed in a laboratory setting might significantly differ from those observed in more naturalistic settings. Unfortunately, no study has examined this hypothesis. This void in the literature is clearly significant because any attempt to apply the psychophysiological findings derived from self-paced exercise protocols performed in laboratory settings to more naturalistic settings could lead to unrealistic conclusions.

The present study was conducted to determine whether the environmental setting (treadmill vs overground) differentially influences physiological, perceptual, and affective responses to exercise at a self-selected pace in healthy men and women. On the basis of previous findings (22,31,32), it was hypothesized that participants would choose a similar or slightly slower walking speed during the treadmill session than during the overground session. However, because treadmill walking requires a different muscle activation pattern than overground walking (26,31), with a significantly greater agonist–antagonist cocontraction of muscles (31), it was hypothesized that the treadmill session would elicit greater physiological responses than the overground session. It was also hypothesized that a higher perceived exertion and a less positive affective valence would occur during the treadmill session compared with the overground session. The influence of factors such as a wider array of external cues or higher attentional distraction in more naturalistic environments would contribute to more favorable perceptual and affective responses to overground exercise than to treadmill exercise. However, because no study has examined both perceptual and affective responses to self-paced exercise in different environmental settings, these hypotheses are more exploratory in nature.

METHODS

Participants. Thirty-four individuals (17 men and 17 women) between 18 and 30 yr volunteered to participate in this study. The experimental procedures were in accordance with the policy statement of the American College of Sports Medicine regarding the use of human subjects and were approved by the Ethics Committee of the Federal University of Parana. Participants gave their written informed consent after explanation of the purpose, experimental procedures, possible risks, and benefits. All participants were in good health, not taking any medication known to influence metabolic or cognitive functions, had a stable body mass (<2.5 kg net change during the previous 3 months), and were nonsmokers. Women were eumenorrheic with a normal menstrual cycle length of 25–32 d and had not taken hormonal contraceptive agents for at least 6 months before their involvement in this study. Moreover, all women studied were in the follicular phase of their menstrual cycle. Subject descriptive data are presented in Table 1.

Experimental design. Each participant completed four sessions, scheduled on different days with at least 48–96 h in-between sessions. During the first session, individuals underwent screening, anthropometric measurements, and familiarization with the experimental procedures. The second session involved a maximal treadmill test. In the two experimental trials, participants performed 20-min bouts of treadmill and overground walking at a self-selected pace, which were completed in a counterbalanced order. All trials were conducted in the morning (between 8:00 and 12:00) under similar environmental conditions. All participants were instructed to refrain from exercise, to avoid caffeinated products in the 24 h preceding the tests, and to present themselves at the laboratory in a 2 h postabsorptive state.

Anthropometric measures. Height (cm; Toledo scale, São Paulo, Brazil) and body mass (kg; Sanny stadiometer, São Paulo, Brazil) were measured according to the techniques described by Gordon et al. (16). Body mass index (BMI, $kg \cdot m^{-2}$) was calculated as body mass divided by height squared. Skinfold thickness measurements were taken with a Lange caliper (Cambridge Scientific Instruments, Cambridge, MA) to the nearest 0.1 mm at the following sites: biceps, triceps, subscapular, and suprailiac. Body density ($g \cdot cm^{-3}$) was then estimated from the equation of Durnin and Womersley (9) and converted to percentage of body fat (%body fat).

Orientation session. The primary purpose of the orientation session was to familiarize the participants with the process of self-selecting an exercise intensity. Each participant was given the following instructions: "select an exercise intensity that you prefer and can be sustained for 20 min and that you would feel happy to do regularly" (29,30). The process of self-selection of an exercise intensity was used during this trial and also during the experimental trials. After the instructions, each individual performed a 5-min bout of walking at a self-selected pace on a motor-driven treadmill (model X Fit 7; Reebok Fitness, London, U.K.) without grade. During this session, participants were allowed to increase, decrease, or maintain the treadmill speed. They were permitted to manipulate the speedometer by pressing the faster or slower arrows on the treadmill control panel *ad libitum*. The speedometer, initially set at 1.11 $m \cdot s^{-1}$ (4.0 $km \cdot h^{-1}$), was covered throughout the trial so that individuals but not investigators were blinded to the actual treadmill speed (6,34). These procedures were repeated one more time after 10 min of seated rest.

TABLE 1. Subject anthropometric characteristics and resting values.

	Men (*n* = 17)	Women (*n* = 17)
Age (yr)	24.0 ± 3.3	22.5 ± 2.6
Body mass (kg)	71.9 ± 10.1	58.8 ± 6.5*
Height (cm)	175.2 ± 6.4	162.5 ± 6.6*
BMI ($kg \cdot m^{-2}$)	23.3 ± 2.2	22.2 ± 1.8
Body fat (%)	18.3 ± 3.2	20.8 ± 3.5**
$\dot{V}O_{2rest}$ ($mL \cdot kg^{-1} \cdot min^{-1}$)	5.4 ± 1.0	4.1 ± 1.0*
HR_{rest} ($beats \cdot min^{-1}$)	62.8 ± 12.2	68.2 ± 9.3

Values are mean ± SD.
* $P < 0.01$, statistically significant difference.
** $P < 0.05$, statistically significant difference.
HR_{rest}, resting HR; $\dot{V}O_{2rest}$, resting oxygen consumption.

Maximal graded treadmill test. In the second visit to the laboratory, participants completed a maximal graded treadmill test using the standard Bruce protocol to assess maximal oxygen consumption ($\dot{V}O_{2max}$). Subjects were verbally encouraged to continue to exercise until the point of volitional exhaustion. The criteria for achieving a $\dot{V}O_{2max}$ required participants to meet two of the following: (a) a plateau in $\dot{V}O_2$ (change of <150 $mL \cdot min^{-1}$ in the last three consecutive 20-s averages), (b) an RER of ≥1.10, and (c) an HR within 10 $beats \cdot min^{-1}$ of the maximal level predicted by age. Therefore, $\dot{V}O_{2max}$ was defined as the highest $\dot{V}O_2$ value attained after reaching the aforementioned criteria. HR_{max} was defined as the highest value recorded during the test. The ventilatory threshold (V_T) was determined by the ventilatory equivalent method (5). Visual inspection to determine the V_T was carried out independently by two experienced investigators. The V_T values detected by the two investigators were then compared. If the two V_T values were within 3% ($mL \cdot min^{-1}$), then those values were averaged and accepted. If the two V_T values were more than 3% different, a third investigator would have independently analyzed the exercise test data to detect V_T (15). However, in the present study, the differences between the V_T values detected by the two investigators did not differ by more than 3% for any participant.

HR ($beats \cdot min^{-1}$) was continuously recorded throughout the test using a Polar Monitoring System (Polar Electro, Oy, Kempele, Finland). $\dot{V}O_2$, carbon dioxide production ($\dot{V}CO_2$), and pulmonary ventilation ($\dot{V}_E$, STPD) were measured on a breath-by-breath basis by a portable gas analysis system (K4 b^2 Cosmed, Rome, Italy). The system was calibrated using room air (21% O_2, 0.03% CO_2) and a certified gas mixture (16% O_2, 5% CO_2; Scott Medical Products, Plumsteadville, PA) before each test. In addition, the turbine flow meter was calibrated with a 3-L syringe before each test.

Each maximal graded treadmill test was preceded by 5 min of quiet, seated rest. The average values of HR and $\dot{V}O_2$ recorded during the last 2 min of seated rest were considered to be the resting values (HR_{rest} and $\dot{V}O_{2rest}$, respectively) (39).

Experimental trials. Within 48–72 h of completing the maximal treadmill test, participants underwent the first experimental trial. As in the orientation session, a set of instructions regarding pace selection were read to the subjects immediately before the trial. The first experimental trial consisted of a 20-min bout of continuous walking at a self-selected pace and was conducted on a motor-driven treadmill with zero grade or on a standard outdoor 400-m track. The second trial (i.e., a 20-min bout of treadmill or overground walking at a self-selected pace) was conducted at least 48 h but not more than 96 h after the first experimental trial.

The self-paced treadmill walking trial began at a speed of 1.11 $m \cdot s^{-1}$ (4.0 $km \cdot h^{-1}$) without grade for 2 min. During the next 3 min of the 20-min trial, subjects were allowed to increase, decrease, or maintain the treadmill speed. They were permitted to manipulate the speedometer by pressing the faster or slower arrows on the treadmill control panel *ad libitum*. After the first 5 min, subjects were allowed to adjust the treadmill speed only every 5 min of the 20-min trial (i.e., minutes 5:00, 10:00, and 15:00). The speedometer was covered throughout the trial so that subjects were blinded to the actual treadmill speed (6,34).

The overground walking trial was conducted on a standard outdoor 400-m tartan track (lane 1). The trial began at a walking speed around of 1.11 $m \cdot s^{-1}$ (4.0 $km \cdot h^{-1}$) for 2 min, and thereafter, the participants were allowed to increase, decrease, or maintain their speed during the next 3 min. After the first 5 min, they were allowed to adjust their walking speed only every 5 min of the 20-min trial (i.e., minutes 5:00, 10:00, and 15:00). The walking speed was determined by a global positioning system, which has been recognized as an accurate measure of overground walking speed (41). These data were integrated to the Cosmed K4 b^2 system. All overground walking trials were conducted during the autumn of 2008. The average temperature for these trials was 20°C. Four overground walking trials were rescheduled because of inappropriate weather conditions. Overground walks were conducted individually to avoid any possible effect of group dynamics or social interaction on the psychophysiological responses to exercise.

The respiratory metabolic measures and HR were recorded every 30 s throughout the experimental trials using the same instruments and procedures as in the graded maximal treadmill test. These physiological responses were then averaged across the final two 30-s intervals of each 5-min stage of the 20-min trials to derive four data points (minutes 5:00, 10:00, 15:00, and 20:00) for each dependent variable. HRR and $\dot{V}O_2R$ were calculated by subtracting HR_{rest} and $\dot{V}O_{2rest}$ values from their respective maximal values (i.e., HR_{max} and $\dot{V}O_{2max}$) (39). Accordingly, for each 5-min interval of the 20-min walking trials, the increment above resting for each value was divided by the calculated reserve and multiplied by 100 to derive %HRR and $\%\dot{V}O_2R$ (39).

Measures of perceived exertion and affect. Perceived exertion was defined as the subjective intensity of effort, strain, discomfort, and/or fatigue that was felt during exercise (27). The Borg 6–20 RPE scale (4) was used to estimate whole-body perceived exertion during exercise. The low and high perceptual anchors for the RPE scale were established during the maximal treadmill test. A rating of 6 (low anchor) was assigned to the lowest exercise intensity, whereas a rating of 20 was assigned to the highest exercise intensity (4). RPE values were estimated during the last 15 s of each 3-min stage of the maximal treadmill test and every 5 min of the experimental trials.

The Feeling Scale (FS) (17) was used as a measure of "basic" or "core" affective valence (pleasure–displeasure). The FS is an 11-point single-item bipolar measure, ranging from −5 to +5, with verbal descriptors at all of the odd integers and at the zero point ("neutral"). The affective valence measured by the FS is a fundamental component of the circumplex model of Russell (37), which incorporates affective valence and activation as orthogonal and bipolar dimensions of the affective space. In the present study, emphasis was placed on affective valence because this dimension has been considered of greatest interest in the context of examining the possible causal link between exercise intensity and adherence (11,19,40). Similar to the RPE scale, the FS was administrated during the last 15 s of each 3-min stage of the maximal exercise test and every 5 min of the experimental trials. Participants were asked to rate how they felt at these particular moments. Standard definitions of perceived exertion and affective valence and separate instructional sets for both the RPE scale and FS scales were read to the subjects immediately before the maximal treadmill test and experimental trials (11,27).

Statistical analysis. Data are shown as means ± SD or SE. Independent *t*-tests were used to examine gender differences in anthropometric characteristics and physiological, perceptual, and affective responses during the graded maximal treadmill test ($P < 0.05$). A series of three-factor, gender (men and women) × environmental setting (treadmill and overground) × time (minutes 5:00, 10:00, 15:00, and 20:00), repeated-measures ANOVA (RM-ANOVA) was conducted on walking speed, $\%\dot{V}O_2R$, %HRR, perceived exertion, and affective valence. Whenever the sphericity assumption was violated, the degrees of freedom were adjusted and reported using the Greenhouse–Geisser epsilon correction. Partial eta squared (η_p^2) was used to determine the size of the effects. For each ANOVA model with a significant environmental setting × time interaction, the simple effects of time were further analyzed within each environmental setting. Significant simple effects of time were followed by planned contrasts in which minutes 10:00, 15:00, and 20:00 values were compared with their minute 5:00 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 0.05/3 = 0.0166. On the basis of a statistical power of 0.80, a moderately large

TABLE 2. Physiological, perceptual, and affective responses to maximal graded treadmill test.

	Men (n = 17)	Women (n = 17)
$\dot{V}O_{2max}$ (mL·kg^{-1}·min^{-1})	57.3 ± 5.9	45.9 ± 5.6*
$\dot{V}O_2 V_T$ (mL·kg^{-1}·min^{-1})	40.1 ± 7.6	34.3 ± 6.4**
$\%\dot{V}O_{2max\ at}\ V_T$	69.6 ± 9.8	74.6 ± 8.9
HR_{max} (beats·min^{-1})	189.8 ± 5.4	190.1 ± 7.0
$HR V_T$ (beats·min^{-1})	155.4 ± 15.5	161.9 ± 15.8
$\dot{V}_E$ (L·min^{-1})	143.1 ± 26.4	100.9 ± 10.0*
RER	1.13 ± 0.08	1.13 ± 1.10
RPE V_T (range = 6–20)	11.7 ± 1.8	12.1 ± 1.5
Affect V_T (−5 to +5)	1.35 ± 1.80	0.88 ± 1.31

* $P < 0.01$, statistically significant.
** $P < 0.05$, statistically significant.
HR_{max}, maximal HR; HRV_T, HR at V_T; RER, maximal RER; RPE V_T, RPE at V_T; $\dot{V}_E$, maximal pulmonary ventilation; $\dot{V}O_{2max}$, maximal oxygen consumption; $\dot{V}O_{2max\ at}\ V_T$, percent of maximal oxygen consumption at V_T; $\dot{V}O_2 V_T$, oxygen consumption at V_T; V_T, ventilatory threshold.

effect size (0.35), and an overall level of significance of 0.05, 14 subjects were required for each of the cells. All data were analyzed using SPSS 17.0 for Windows (SPSS, Inc., Chicago, IL).

RESULTS

Descriptive data. The descriptive data of the participants are shown in Table 1. There were no gender-based differences in age, BMI, and HR_{rest}. However, men were significantly heavier and taller ($P < 0.01$) and had a lower percent body fat than women ($P < 0.05$). $\dot{V}O_{2rest}$ was significantly higher in men than in women ($P < 0.05$).

Maximal treadmill test. There were no gender differences in HR_{max}, HRV_T, and RER (Table 2). However, $\dot{V}O_{2max}$, $\dot{V}O_2 V_T$, and maximal $\dot{V}_E$ were significantly higher in men than in women ($P < 0.05$). The perceptual and affective responses linked to the V_T did not differ between men and women.

Experimental trials. The treadmill and overground walking speeds during the 20-min bouts of self-paced exercise are shown in Figure 1. There were significant main effects of environmental setting ($F_{1,32}$ = 63.724, $P < 0.01$, η_p^2 = 0.666) and time ($F_{2.069,66.196}$ = 19.545, $P < 0.01$, η_p^2 = 0.379). In addition, there was a significant interaction between these two factors ($F_{1.648,52.745}$ = 28.061, $P < 0.01$, η_p^2 = 0.467). This indicates that the changes in walking speed during the 20-min bouts of self-paced exercise differed as a function of the environmental setting. Therefore, the interaction was decomposed into the simple effects of time within each environmental setting. For overground walking, the effect of time was not significant ($P > 0.05$). On the other hand, there was a significant effect of time for treadmill walking ($F_{1.769,58.382}$ = 79.462, $P < 0.01$, η_p^2 = 0.707). Planned contrasts on the treadmill walking speed data demonstrated that the walking speed was significantly slower during the first 5 min of exercise when compared with minutes 10:00, 15:00, and 20:00 ($P < 0.0166$). Moreover, there were significant main effects of gender ($F_{1,32}$ = 6.430, $P < 0.05$, η_p^2 = 0.167) and significant gender × environmental setting interaction ($F_{1,32}$ = 4.432, $P < 0.05$, η_p^2 = 0.122). Specifically, men self-selected a faster walking speed than women, irrespective of environmental setting. No significant gender × time or gender × environmental setting × time interactions were noted ($P > 0.05$).

The $\%\dot{V}O_2R$ responses to 20-min bouts of treadmill and overground walking at a self-selected pace are presented in Figure 2A. There were significant main effects of environmental setting ($F_{1,32}$ = 9.639, $P < 0.01$, η_p^2 = 0.231) and time ($F_{1.816,58.127}$ = 31.636, $P < 0.01$, η_p^2 = 0.497). In addition, there was a significant interaction effect between these two factors ($F_{1.998,63.928}$ = 22.028, $P < 0.01$, η_p^2 = 0.408). This indicates that the changes in the $\%\dot{V}O_2R$ responses during 20-min bouts of self-paced exercise differed as a function of the environmental setting. Therefore, the interaction was decomposed into the simple effects of time within each environmental setting. For treadmill walking, the effect of time was significant ($F_{1.824,60.206}$ = 33.013, $P < 0.01$, η_p^2 = 0.500). Planned contrasts on the $\%\dot{V}O_2R$ data found that the $\%\dot{V}O_2R$ was significantly lower at minute 5:00 compared with minutes 10:00, 15:00, and 20:00 ($P < 0.0166$).

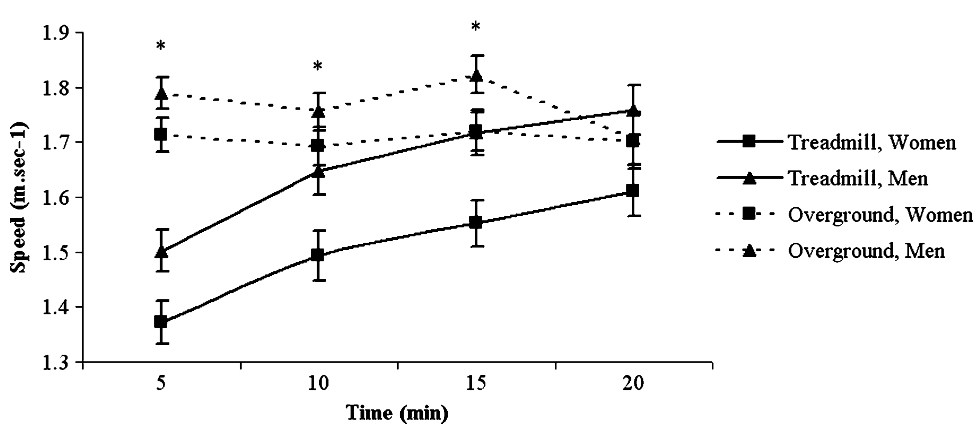

FIGURE 1—Treadmill and overground walking speed (m·s^{-1}) during the 20-min bouts of self-paced exercise. Data are shown as means ± SE. *$P < 0.05$, significantly different from treadmill session.

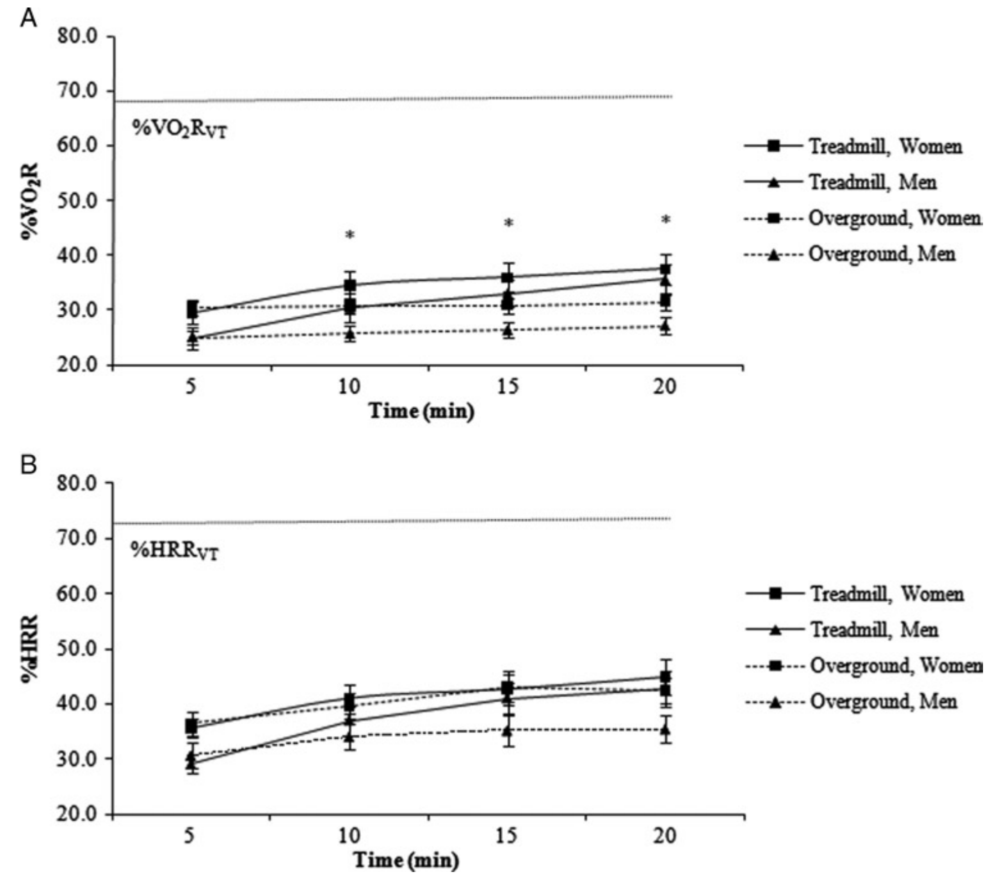

FIGURE 2—The %$\dot{V}O_2$R (A) and %HRR (B) responses to 20-min bouts of treadmill and overground walking at a self-selected pace. Data are shown as means ± SE. *P < 0.05, overground session significantly different from treadmill session.

In contrast, there was no significant effect of time for overground walking ($P > 0.05$). Similarly, there were no significant main effects of gender and gender × environmental setting, gender × time, or gender × environmental setting × time interactions ($P > 0.05$).

The %HRR responses to 20-min bouts of treadmill and overground walking at a self-selected pace are shown in Figure 2B. There was no significant main effect of environmental setting ($P > 0.05$). In contrast, there was a significant main effect of time ($F_{3,96} = 37.251$, $P < 0.01$, $\eta_p^2 = 0.538$) as well as a significant environmental setting × time interaction ($F_{3,96} = 5.306$, $P < 0.01$, $\eta_p^2 = 0.142$). This demonstrates that the changes in the %HRR responses during 20-min bouts of self-paced exercise differed as a function of the environmental setting. Therefore, the interaction was decomposed into the simple effects of time within each environmental setting. For overground walking, the effect of time was significant ($F_{3,99} = 9.521$, $P < 0.01$, $\eta_p^2 = 0.224$). Planned contrasts on the %HRR data indicated that the %HRR was significantly lower at minute 5:00 compared with those at minutes 15:00 and 20:00 ($P < 0.0166$) but was similar to that at minute 10:00. In a similar manner, there was a significant effect of time for treadmill walking ($F_{1.719,56.720} = 36.918$, $P < 0.01$, $\eta_p^2 = 0.528$). Planned contrasts revealed that the %HRR was significantly lower at minute 5:00 when compared with minutes 10:00, 15:00, and 20:00 ($P < 0.0166$). There was no significant main effect of gender ($P > 0.05$). Moreover, there were no significant gender × environmental setting, gender × time, and gender × environmental setting × time interactions ($P > 0.05$).

Perceived exertion responses to 20-min bouts of treadmill and overground walking at a self-selected pace are presented in Figure 3A. There were significant main effects of envi- F3
ronmental setting ($F_{1,32} = 6.370$, $P < 0.05$, $\eta_p^2 = 0.166$) and time ($F_{1.129,55.336} = 27.647$, $P < 0.01$, $\eta_p^2 = 0.464$). In addition, there was a significant interaction between these two factors ($F_{1.952,62.451} = 11.377$, $P < 0.01$, $\eta_p^2 = 0.262$). This indicates that the changes in the perceived exertion responses during 20-min bouts at a self-selected pace differed as a function of time. Therefore, the interaction was decomposed into the simple effects of time within each environmental setting. For overground walking, the effect of time was significant ($F_{1.352,96.735} = 5.890$, $P < 0.05$, $\eta_p^2 = 0.151$). Planned contrasts found that the perceived exertion was significantly lower at minute 5:00 compared with that at minute 20:00 ($P < 0.0166$) but was not significantly different with those at minutes 10:00 and 15:00. Also for treadmill walking, there was a significant effect of time ($F_{2.149,70.763} = 37.795$, $P < 0.01$, $\eta_p^2 = 0.534$). Planned contrasts revealed that the perceived exertion was significantly lower at minute 5:00

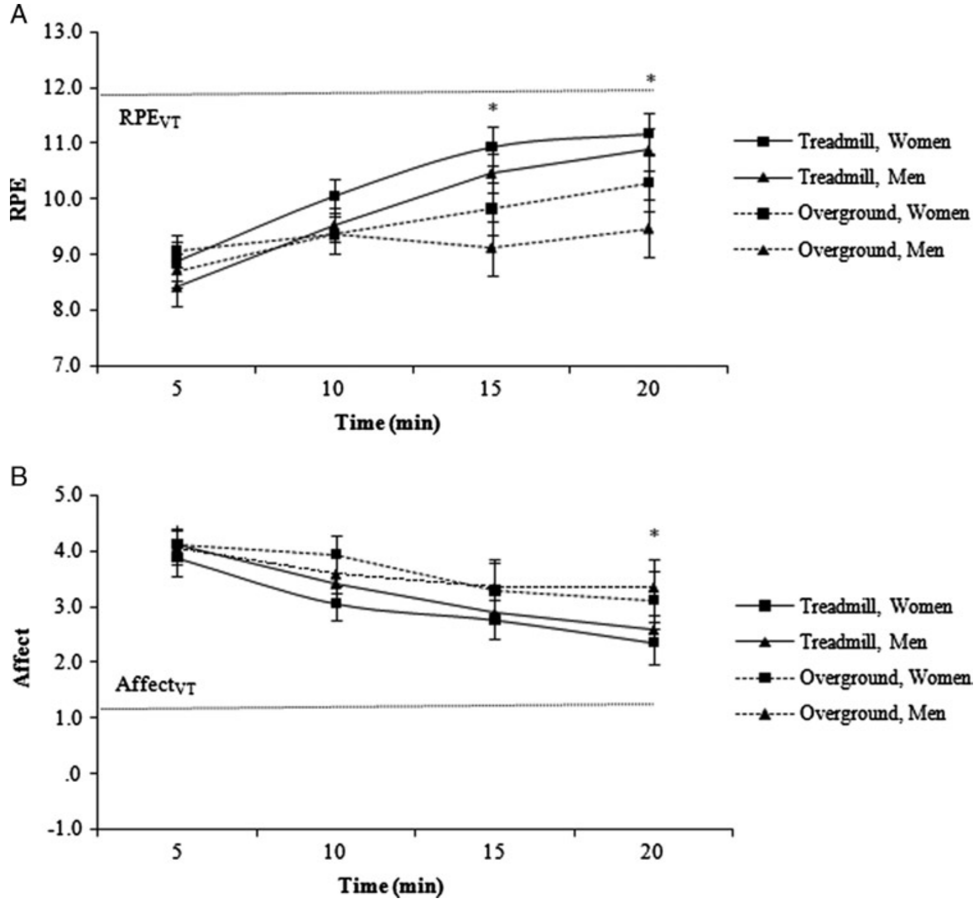

FIGURE 3—Perceived exertion (A) and affective (B) responses to 20-min bouts of treadmill and overground walking at a self-selected pace. Data are shown as means ± SE. *P < 0.05, overground session significantly different from treadmill session.

when compared with those at minutes 10:00, 15:00, and 20:00 ($P < 0.0166$). There was no significant main effect of gender ($P > 0.05$). Moreover, there were no significant gender × environmental setting, gender × time, and gender × environment setting × time interactions ($P > 0.05$).

Affective responses to 20-min bouts of treadmill and overground walking at a self-selected pace are shown in Figure 3B. There were significant main effects of environmental setting ($F_{1,32} = 10.708$, $P < 0.01$, $\eta_p^2 = 0.251$) and time ($F_{2.370,75.844} = 34.884$, $P < 0.01$, $\eta_p^2 = 0.522$). In particular, a less positive affective response occurred during treadmill walking than during overground walking. However, affective responses to exercise tended to decrease over time in both environmental settings. There was no significant interaction between environmental setting and time. As a result, the environmental settings were collapsed for planned contrasts that compared the minute 5:00 value with the minutes 10:00, 15:00, and 20:00 values. These analyses revealed significant decreases in affective responses (in comparison with minute 5:00 values) at minutes 15:00 and 20:00 ($P < 0.0166$) but not at minute 10:00 for the two environmental settings. There was no significant main effect of gender ($P > 0.05$). In addition, there were no significant gender × environment setting, gender × time, and gender × environment setting × time interactions ($P > 0.05$).

DISCUSSION

The purpose of this study was to determine whether environmental setting differentially influences physiological, perceptual, and affective responses to exercise at a self-selected pace. To examine this objective, the present research design involved participants performing two bouts (i.e., treadmill or overground) of self-paced walking on separate days and administered in a counterbalanced order. As expected, participants were predisposed to choose a slower walking speed during the treadmill session when compared with the overground session. However, a greater physiological response occurred during treadmill walking than during overground walking. Moreover, a higher perceived exertion and a less positive affective valence were reported by the participants during the treadmill session when compared with the overground session. In this context, the main findings of the present study demonstrate that not only physiological but also perceptual and affective responses to a self-paced exercise are influenced by the environmental setting.

As noted by several authors (14,22,31,34), overground walking has been considered one of the most common and practical forms of physical activity. However, it is obvious that many environmental barriers such as lack of safety or extreme weather conditions can negatively affect the regular practice of overground walking. In this regard, many physical activity programs have used treadmills as a substitute for overground walking. However, a question that arises is whether treadmill walking is an ecologically valid surrogate for overground walking. Unfortunately, few studies have been done to answer this question. Parvataneni et al. (31) have found that treadmill walking at self-selected pace involves a greater metabolic requirement when compared with overground walking, possibly because of a greater agonist–antagonist cocontraction of muscles. This finding is in line with the results of the present study. Subjects selected a slower walking speed during the treadmill session than during the overground session. However, a similar or even a greater physiological response to self-paced walking in the treadmill session than in the overground session was noted in the present study. More importantly, it should be noted that participants selected walking paces that corresponded to exercise intensities that were below the intensity range recommended by the American College of Sports Medicine (1) to provide fitness and health benefits, irrespective of environmental setting. This finding is in contrast with previous laboratory-based studies (6,13,21,29). Nevertheless, in a recent study conducted on 60 healthy college-aged women, Pintar et al. (34) found that higher- and lower-fitness participants were predisposed to self-select exercise intensities as low as 39% and 52% $\dot{V}O_{2max}$, respectively, during a 15-min bout of treadmill walking. A potential explanation for these findings may be related to the age of the participants. In fact, in a recent meta-analytic study, Ekkekakis (10) argues that young adults tend to choose exercise intensities that are below the lower boundaries proposed by the American College of Sports Medicine (1), unless they are specifically instructed to select an intensity for exercise. Therefore, from a practical standpoint, the findings of the present study underscore the importance for health practitioners not only to redirect their efforts toward identifying young participants predisposed to select suboptimal exercise intensities but also to provide consultation designed to enhance the self-regulatory skills of participants.

Previous laboratory-based studies (6,13,21,35) using self-paced exercise protocols have shown that individuals do not merely select a singular walking speed throughout an exercise bout but use instead a type of pacing strategy. Specifically, they exhibit a tendency to gradually increase their walking speed during the initial minutes of exercise, without any significant changes thereafter (6,13,21). The reasons for this phenomenon remain unclear. However, Ekkekakis (10) has speculated that this represents an exploratory strategy of searching for the walking pace beyond which any additional increase would lead to a decrease in pleasure. In the present study, the participants continued to increase their walking speed not only in the initial stages of exercise but also across the duration of the 20-min exercise bout. Interestingly, this increase in the walking speed was exclusively noted in the treadmill setting given that, in the overground setting, the participants tended to select a continuous walking speed until the end of the 20-min exercise bout. Again, the reason for this finding is not clear, but the experience of walking in more natural environments may make it easier for individuals to identify their preferred overground walking pace.

It has been proposed that, when examining the exercise intensity–affect relationship, exercise intensity should be defined in relation to the ventilatory (or lactate) threshold to ensure physiological equivalence between individuals (11). When compared with the $\dot{V}O_2$ values recorded at ventilatory threshold during the maximal treadmill test, $\dot{V}O_2$ values calculated from the two environmental settings revealed that participants self-selected an exercise intensity significantly below the ventilatory threshold in both treadmill and overground sessions. These findings are similar to those reported by previous studies using self-paced exercise protocols (6,13,21,35), which show that, on average, individuals choose to exercise at intensities below or around the ventilatory threshold. These findings are also consistent with the fundamental assumptions of the dual-mode model proposed by Ekkekakis et al. (11), which suggests an interplay of cognitive appraisal processes and interoceptive cues in the generation of affective responses during exercise. According to this model, cognitive appraisal processes are the primary determinant of affective responses when the exercise intensity is below or near the ventilatory threshold. At these exercise intensities, homeostasis is not threatened, and affective responses are pleasant for most people. Once the exercise intensity exceeds the ventilatory threshold, interoceptive cues gain salience and become the primary determinant of affective responses. At exercise intensities beyond the ventilatory threshold, homeostasis is threatened, and affective responses tend to be homogeneously negative (11). In this context, it is not surprising that participants reported homogeneous, positive affective responses during both treadmill and overground self-paced walking bouts. In particular, they reported affective responses, on average, varying from +2 (i.e., between "fairly good" and "good") to +4 (i.e., between "good" and "very good"), irrespective of environmental setting. A positive affective response generated by exercise may lead to greater enjoyment of the exercise session, promote a positive memory of that activity, and, consequently, contribute to increased motivation for future physical activity behavior (10,29,36). However, it should be noted that participants reported a significantly less pleasant experience during treadmill walking than during overground walking, thus suggesting that subtle increases in the self-selected exercise intensity (19), along with the characteristics of the laboratory setting, may negatively affect their exercise experience.

Although the affective responses experienced during exercise may ultimately play a significant role in predicting adherence to a physical activity program, the perceptual responses also have consequences for future physical activity behavior (20,40). Indeed, in a recent prospective study, Williams et al. (40) found that affective responses to exercise predicted self-reported physical activity 6 and 12 months later. However, this relationship between affective responses and future physical activity participation became nonsignificant after controlling for RPE. Therefore, the assessment of both affective ("how" a person feels) and exertional ("what" a person feels) responses may result in a more complete description of subjective experiences to exercise. This strategy may lead to the identification of individuals predisposed to reduced future physical activity participation. In the present study, participants reported perceived exertion values, on average, varying from 8 (i.e., between "extremely light" and "very light") to 11 (i.e., "light") on the Borg RPE scale, irrespective of environment setting. These results are in agreement with those findings reported by previous laboratory-based studies using self-paced exercise protocols (6,8,34). However, it should be noted that, in the present investigation, perceived exertion responses to the self-paced walking bout performed on a treadmill were significantly higher when compared with the self-paced overground session. On the basis of the principles of Borg's (4) model of effort continua, the higher exertional perceptions reported by the participants during treadmill walking are directly related to the greater physiological requirements during this session. However, the influence of other factors, such as wider array of external cues (e.g., scenery, weather, breeze) and higher attentional distraction, might also have contributed to more favorable perceptual and affective responses during overground walking than during treadmill walking.

The present study simultaneously examined perceptual and affective responses to self-paced exercise protocols in different environmental settings. Moreover, this study also provided new insights into the role of gender differences on psychophysiological responses to exercise at a self-selected pace. Specifically, the current findings reveal that men and women are predisposed to choose different walking speeds but have similar psychophysiological responses to self-paced exercise, regardless of environmental setting. However, it should be noted that the subjects in the present investigation were healthy, physically active, young adults. On the one hand, this cohort may not be representative of the adult population at large. On the other hand, this population is appropriate for a preliminary exploration of the influence of environmental settings on psychophysiological responses to self-paced exercise protocols. Therefore, the present findings cannot be applied to older adults or to individuals with chronic diseases. Similar research with more diverse populations is needed.

It should be acknowledged that the instructions given to participants may influence their preferential choice of an exercise intensity (10,30,35). In the present study, the participants were asked to "select an exercise intensity that you prefer…that you would feel happy to do regularly" (29,30,35). As noted by Rose and Parfitt (35), this particular set of instructions may lead some individuals to understand it as "select an intensity which makes you feel happy," which, in turn, would affect the affective responses during exercise. Thus, it is unclear whether the positive affective responses during the self-paced treadmill and overground exercise bouts are because of any potential misinterpretation of the instructions or because of the choice itself in both environmental settings. However, previous laboratory-based studies (6,13,21) using self-paced exercise protocols but with different instructional sets have found similar affective responses to exercise. Importantly, the present study did not approach the measurement of affect through the circumplex model of Rose and Parfitt (35), which incorporates affective valence and activation as orthogonal and bipolar dimensions. Although Ekkekakis et al. (12) have argued that the use of both dimensions provides a more complete examination of the affective experience during exercise, the present investigation did not include the measurement of activation because the activation dimension of the circumplex model was not central to the purposes of this study. Moreover, in this study, affective responses were repeatedly assessed during the two 20-min bouts of self-paced exercise. The repeated assessment of affect could be considered a strength of this investigation because few studies have embraced this methodological approach (12). However, studies have suggested that affective responses should be assessed not only during exercise but also immediately after exercise (2,3,12). It may be that the trajectory of pleasure–displeasure during and after exercise actually exhibits two distinct phases. The first phase involves a decline of affective responses during exercise, whereas the second phase involves an improvement or "rebound" of affective responses after exercise (2). In contrast, recent studies have found that the affective responses can increase not only during exercise but also after exercise (12,30). Further studies should continue to examine the time course of affective valence during the postexercise period. Finally, the present study did not control for the effects of any dispositional (extraversion, neuroticism, behavioral inhibition) or situational (self-efficacy) variables on self-selection of exercise pace. It is likely that a degree of the observed variation in the self-selection of exercise pace may be accounted for by psychological variables.

CONCLUSIONS

This study has provided further evidence that physiological, perceptual, and affective responses to a self-paced exercise are influenced by the environmental setting. Specifically, a self-paced overground walking protocol results in a lower exercise intensity, reduced perceived exertion, and more pleasant affective valence when compared with a self-paced treadmill walking protocol in healthy men and women. These results have both theoretical and practical significance. From a theoretical perspective, the present study provides useful insight into how environmental settings influence the selection of an exercise pace as well as the associated perceptual and affective responses. These findings might be taken into account by researchers when designing studies to assess psychophysiological responses to self-paced exercise. More importantly, from a practical perspective, it seems that individuals typically choose an exercise pace that makes them feel good, which may create a positive memory of the activity and hopefully lead to increased motivation for future physical activity participation. In addition, self-paced exercise performed in a more naturalistic setting may lead to lower perception of exertion and more positive affective valence than self-paced exercise performed in a laboratory setting, thus possibly improving adherence to a physical activity program.

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AQ1 = Please check if "1" in "($\dot{V}O_2R$) or HR reserve (HRR) 1" should be retained.

AQ2 = The citation of Table 2 was inserted here. Please check if this is appropriate.

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