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Affective, Exercise and Physical Activity among Healthy Adolescents

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Abstract

Many adolescents do not meet public health recommendations for moderate-to-vigorous physical activity (MVPA). In studies of variables influencing adolescent MVPA, one that has been understudied is the affective response to exercise. We hypothesized that adolescents with a more positive affective response to acute exercise would be more active. Adolescents (N = 124; 46% male) completed two 30-minute exercise tasks (above and below the ventilatory threshold [VT]), and wore Actigraph® accelerometers for 6.5 ± 0.7 days. Affective valence was assessed before, during and after each task. A more positive affective response during exercise below the VT was associated with greater participation in MVPA ($p < .05$). The results are consistent with the hypothesis that individuals who have a more positive affective response to exercise will engage in more MVPA. To promote greater participation in MVPA among adolescents, programs should be designed to facilitate a positive affective experience during exercise.

Keywords

Fitness; Feeling State; Accelerometers

Recent population-based data obtained from adolescents in the United States continue to demonstrate that the majority of adolescents are failing to engage in recommended levels of physical activity; levels that are associated with markedly better health outcomes over the short and long term. Estimates of the proportion of adolescents between the ages of 14 and 17 years who meet the current recommendation of at least 60 minutes of moderate-to-vigorous physical activity (MVPA) on most days are consistently below 50% (Butcher, Sallis, Mayer, & Woodruff, 2008; Eaton et al., 2006). Meanwhile, evidence continues to accumulate that physical activity during the childhood years has a powerful influence on health (Physical Activity Guidelines Advisory Committee, 2008; Rowland, 2007). Encouraging greater participation in physical activity among adolescents offers a promising avenue toward improving the health status of current and future generations.

To effectively promote adolescent physical activity, it is necessary to understand the factors that influence the choices adolescents make related to being physically active. Many studies

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have examined the correlations between physical activity and demographic, social and cognitive factors among adolescents (Van Der Horst, Paw, Twisk, & Van Mechelen, 2007). These studies have provided useful information for designing interventions targeting adolescents' activity levels, and some of these interventions have impacted physical activity (Haerens et al., 2006; Schneider et al., 2007). However, the effects tend to be modest in relation to the resources expended (Webber et al., 2008). A systematic review of clinical trials promoting physical activity in adolescents found that fewer than half had a significant impact on activity levels (Van Sluijs, McMinn, & Griffin, 2008). More recently, investigators have begun to explore variables outside of the traditional social-cognitive set, including both environmental (Gordon-Larsen, McMurray, & Popkin, 2000) and affective (Williams, 2008) factors. Research on the role of exercise-associated affect has become increasingly refined and some studies suggest that a better understanding of these refinements may play an important role in physical activity decision-making and adherence. This research is in its early phase with many questions still needing to be answered.

The most recent research into the association between affect and physical activity has evolved from basic studies demonstrating that physical activity makes people feel better to research that takes into account interoceptive and cognitive cues at different exercise intensity levels, as well as important individual differences that might influence the affective responses both during and following exercise bouts. Earlier studies focused exclusively on group averages, overlooking differences between individuals, but current evidence shows that there is considerable inter-individual variability in the affective response to exercise (Welch, Hulley, Ferguson, & Beauchamp, 2007). Moreover, this inter-individual variability seems to be more apparent during low-to-moderate-intensity exercise than during high-intensity exercise (Rose & Parfitt, 2007). These empirical findings are consistent with the dual-mode model of exercise-associated affect (Ekkekakis, Hall, & Petruzzello, 2005), which posits that differences in affect during low-to-moderate-intensity exercise are primarily determined by cognitive influences, whereas affect during higher intensity exercise is primarily determined by interoceptive influences. Specifically, this model suggests that exercise below the ventilatory threshold (the intensity level at which there is an abrupt increase in blood lactate or a nonlinear increase in expired carbon dioxide relative to oxygen consumption) will have a positive impact on affect for most people, and individual differences become increasingly apparent as the intensity approaches the ventilatory threshold. Above the ventilatory threshold, the affective response to exercise will be negative for most people, predominantly shaped by the aversive sensations that accompany an accumulation of lactic acid at higher intensities. Thus, the dual-mode model of exercise-associated affect provides a useful theoretical framework for understanding how the affective response to exercise differs across intensities and individuals.

Moreover, most of the past research on the affective response to exercise had overlooked the affective response of the exerciser *during* exercise, and had been confined to comparing only pre- and post-exercise affect. With the advent of research designs assessing affect during the actual exercise bout, it has become evident that during exercise of a higher intensity most individuals experience a decline in their affective valence (Ekkekakis et al., 2005; Welch et al., 2007). This transient response to the exercise stimulus was obscured in earlier studies because there tends to be an immediate rebound following termination of an exercise bout (Ekkekakis, Hall, & Petruzzello, 2008; Sheppard & Parfitt, 2008), particularly at higher intensities, so that pre-post comparisons typically show a positive impact of both moderate- and hard-intensity exercise on affect. More current studies that have measured the affective response during exercise find that participants are likely to feel better during low-to-moderate-intensity exercise than they do during high-intensity exercise, which often makes them feel worse (Backhouse, Ekkekakis, Biddle, Foskett, & Williams, 2007; Ekkekakis et al., 2008; Sheppard & Parfitt, 2008; Welch et al., 2007).

The affective response to exercise is not only of interest because of its potential for enhancing psychosocial well-being but also for promoting adherence to regular physical activity. Hedonic theory holds that people will be motivated to engage in behaviors that bring them pleasure and to avoid activities that are accompanied by feelings of displeasure (see discussion in Williams, 2008). According to this theory, an individual who experiences positive affect in conjunction with physical activity will be more likely to lead an active lifestyle as compared to an individual who experiences negative affect in conjunction with physical activity. To date, there is very little research that has attempted to test this hypothesis. A notable exception is a study by Williams et al. (2008), in which adults' affective responses to exercise at a moderate intensity prior to an intervention was predictive of their self-reported physical activity 6 and 12 months later. Evidence consistent with the hedonic hypothesis also comes from a cross-sectional study (Kiviniemi, Voss-Humke, & Seifert, 2007) in which adults' affective associations with exercise (i.e., the way that they reported feeling when considering exercise) were correlated with their self-reported physical activity participation. These two studies offer preliminary data related to the hedonic hypothesis of physical activity participation.

The present study builds on the findings described above and tests the hypothesis that affective responses to exercise will be associated with physical activity participation by adolescents. Specifically, we hypothesized that adolescents with a positive affective response to an acute exercise bout would be more physically active than would adolescents with a neutral or negative affective response to an acute exercise bout. We further expected, based on the dual-mode model of exercise and affect, that the association between affective response to exercise and physical activity would be stronger when evaluated with respect to a moderate-intensity exercise task (i.e., below the ventilatory threshold) than when evaluated with respect to a hard-intensity exercise task (i.e., above the ventilatory threshold). The dual-mode model posits that the negative affective response during exercise above the ventilatory threshold is virtually universal (Ekkekakis et al., 2005), thus suggesting that the affective response to hard-intensity exercise would not predict engagement in moderate or vigorous intensity physical activity. In addition, we anticipated that the association between the affective response to exercise and exercise participation would be evident when examining the affective response during exercise, but would not be present when examining the affective response after exercise, since evidence points to a relatively uniform "rebound" into positive affective territory following the cessation of exercise (Parfitt, Eston, & Connolly, 1996; Reed & Ones, 2006; Sheppard & Parfitt, 2008; Welch et al., 2007).

Methods

Participants

One hundred and ninety-two healthy adolescents (54.7% male; 62% Caucasian, 21% Latino, 10% Asian, 4% multi-racial, 5% other; mean [SD] age = 14.78 [.45] years, range = 14–16) were recruited from two public high schools in Southern California that were demographically similar to one another and agreed to facilitate participant recruitment using school mailing lists. In order to be eligible for the study, participants had to meet the following criteria: (a) no health problems that precluded participating in regular moderate to vigorous exercise; (b) right-handed (scoring as right-hand dominant on the Chapman scale, Chapman & Chapman, 1987); (c) a self-report of no history of neurological disorders, stroke, or significant head trauma (i.e., head trauma associated with loss of consciousness for greater than 24 hours); (d) not clinically depressed (defined as ever having been diagnosed with clinical depression or scoring at least 20 on the Beck Depression Inventory (Beck, Steer, & Brown, 1996). Criteria related to handedness, neurological well-being and depression were employed to control for factors that might influence electroencephalogram recordings, which were obtained as part of the larger study (data reported elsewhere).

Measures

Cardiovascular fitness—Each participant performed a progressive ramp-type cycle-ergometer exercise test to the limit of his or her exercise tolerance. Subjects were vigorously encouraged during the high-intensity phases of the exercise protocol. Gas exchange was measured breath-by-breath (Cooper, Weiler-Ravell, Whipp, & Wasserman, 1984) and the ventilatory threshold and peak VO_2 (oxygen consumption) were calculated using a Sensor Medics metabolic system (VIASYS, Yorba Linda, CA).

Dual energy x-ray absorptiometry (DEXA)—Percent body fat was determined by dual energy x-ray absorptiometry (DEXA) using a Hologic QDR 4500 densitometer (Hologic Inc., Bedford, MA). Participants were scanned in light clothing while lying supine. DEXA scans were performed and analyzed using pediatric software. On the day of each test, the DEXA instrument was calibrated using procedures provided by the manufacturer.

Body mass index (BMI)—Standard, calibrated scales and stadiometers were used to determine BMI (weight/height^2). BMI percentile for each participant was calculated using published standards from the Centers for Disease Control and Prevention (National Center for Health Statistics, 2004).

Physical activity—Physical activity level was measured using an Actigraph® accelerometer (model 7164), ActiGraph, Pensacola, Florida), a lightweight uniaxial ambulatory monitor that measures acceleration in the vertical plane. Actigraphs® have been found to accurately measure activity when worn on the hip (Freedson, Melanson, & Sirard, 1998). The Actigraph® monitors were attached to an adjustable nylon belt, and participants were instructed to wear the monitor on their left hip for seven consecutive days. Participants were informed that they should remove the Actigraph® while sleeping, swimming, or bathing, and were provided with a small portable diary on which to record any instances that the device was removed. The activity monitors were set to sample at 60-s time intervals, so data were obtained as counts per minute.

Affective valence—The Feeling Scale (FS) is a single-item 11-point bipolar measure of pleasure-displeasure, which is used for the assessment of affective valence. The scale ranges from - 5 (very bad) to + 5 (very good). Respondents are asked to rate “how you feel right now.” Originally developed by Hardy and Rejeski (1989), the FS has been shown to be only moderately related to ratings of perceived exertion, suggesting that the two constructs are distinct. Moreover, recent work has demonstrated that the FS is sensitive to alterations in exercise intensity among adolescents during exercise (Sheppard & Parfitt, 2008) and is positively related to enjoyment of acute exercise (Robbins, Pis, Pender and Kazanis, 2004). Participants gave FS ratings prior to commencing each exercise task (baseline), during each exercise task (10 and 20 minutes) and after each task (30 and 40 minutes).

Ratings of perceived exertion (RPE)—Borg’s RPE scale (Borg, 1982, 1998) was developed to provide a rating scale that permits the individual to report his or her overall level of perceived exertion based on his or her own physiological and psychological perceptions. In the present study, the RPE scale was employed as a manipulation check to verify that individuals perceived themselves to be working at different levels of exertion during the moderate and hard tasks. This scale ranges from 6 (no exertion at all) to 20 (maximal exertion). Participants were asked to provide a rating on the RPE scale every three minutes (excluding baseline) throughout the exercise tasks.

Heart rate—Heart rate was recorded continuously using a Sensor Medics V-max system (VIASIS, Yorba Linda, CA) via Cardio System software using a three-lead ECG. Every three minutes during the exercise task an exercise technician recorded the current heart rate on an exercise data sheet.

Procedures

Recruitment—Participants were recruited using flyers mailed to all high school freshmen at the two schools. An initial telephone screening was followed by an orientation session during which potential participants completed consent forms and screening questionnaires. All participants provided written assent to participate, and written consent was also obtained from a parent or guardian. All study procedures were reviewed and approved by a University-based Institutional Review Board.

Assessments—Assessments were conducted at a University-based General Clinical Research Center (GCRC). Study participants visited the GCRC three times, with each visit separated by approximately one week. During the first visit, participants underwent a cardiovascular fitness test and received the Actigraph®. Participants were instructed to wear the Actigraph® for 7 days on a belt over their left hip during all waking hours except during water sports or bathing.

Using the V-slope method, each participant's ventilatory threshold was determined by the exercise technician who performed the cardiovascular fitness test. The V-slope method is used to identify "the transition in the CO_2 production rate in the muscles that occurs when lactic acid is produced faster than it is catabolized (Beaver, Wasserman, and Whipp, 1986, p. 2025)". This point, at which there is a break in the slope depicting the relationship of CO_2 production to O_2 uptake, was confirmed by visual inspection of the data, and the work rate at the ventilatory threshold was used to calculate the target work rate for the moderate and hard exercise tasks as described below. The selection of the ventilatory threshold as a reference point for assigning exercise of different intensities was based on evidence that exercise above the ventilatory threshold is qualitatively different from exercise below the ventilatory threshold, and has been shown to have differential effects on affect (Ekkekakis et al., 2008; Welch et al., 2007).

During the second visit to the GCRC, participants completed a 30-minute exercise task on a cycle ergometer. Prior to initiating the task, participants reported their affective valence using the Feeling Scale (FS). Throughout the task, and after a 10-minute recovery period, participants were asked to provide a rating on the FS every 10 minutes. Heart rate and ratings of perceived exertion were obtained every 3 minutes throughout the exercise task. The exercise task was repeated at a third visit to the clinic, with visits two and three randomly determined to be either below the ventilatory threshold (a moderate intensity; target work rate equivalent to 80% of the work rate at the participant's ventilatory threshold) or above the ventilatory threshold (a hard intensity; target work rate equivalent to the work rate at the mid-way point between the individual's peak oxygen uptake during the fitness test (VO_2peak) and the ventilatory threshold). Exercise technicians were instructed to be alert for signs of fatigue on the part of participant, and to reduce the target work rate in increments of 5–10 watts after the first five minutes of exercising, as needed, to ensure that the participant would be able to complete the 30-minute task. Participants were not informed a priori as to the intensity level that they would be exercising. Participants received $25 monetary compensation following each clinic visit.

Actigraph® data reduction—Minute-by-minute accelerometer counts were classified as moderate-to-vigorous physical activity (MVPA) using both the widely-used cut-off of 1,953 counts/min (Freedson et al., 1998) and the recently suggested alternative cut-off of 760 counts/min (Matthews, 2005; Welk, McClain, Eisenmann, & Wickel, 2007). Daily total accumulated minutes of MVPA were computed for each of the days that the Actigraph® was worn for at least 8 valid hours. A valid hour was defined as one that did not contain a string of 30 or more zeros. Participants with fewer than 4 valid days of monitoring (n = 24) and an additional 37 participants with fewer than 2 weekend days monitored were excluded from the analyses. Four days has been suggested as the minimum number of days of monitoring for obtaining a reliable estimate of physical activity in adolescents (Trost, McIver, and Pate, 2005). The average number of valid days in the final sample was 6.54 +/− .73 days. Four alternative means of summarizing the Actigraph® data were utilized: (a) the average daily minutes spent in MVPA; (b) the average daily minutes spent in moderate-intensity activity (MVPA below 5724 counts/min); (c) the average daily minutes spent in vigorous-intensity activity (at or above 5724 counts/min); and (d) the proportion of valid monitoring days on which the individual met recommended activity guidelines (i.e., engaged in at least 60 minutes of MVPA).

Affective data reduction—Ratings on the FS were averaged to yield a mean FS during the exercise tasks (i.e., the average of ratings at 10 and 20 minutes) and after the exercise tasks (i.e., the average of ratings at 30 and 40 minutes). The differences between these continuous variables and baseline FS (i.e., change in FS) were used to test the study hypotheses. For descriptive purposes, the differences were then used to classify participants into categories that characterized their affective responses during each exercise task: (a) those that experienced a decline in affective valence; (b) those that experienced no change in affect; and (c) those that experienced an improvement in affective valence.

Data Analysis

Seven participants were dropped from the analyses because they failed to complete one of the exercise task visits. In one case, a single data point was missing from the assessment of FS during the exercise task; the missing value was replaced using the FS value from the other during-exercise time point. Thus, the final sample size for the analyses was 124. Manipulation checks (repeated measures ANOVAs) were run to confirm that there was an effect of the exercise tasks on heart rate, RPE, and FS. Regression analyses examined the relationship of change in FS to physical activity participation[1]. All regression equations controlled for cardiovascular fitness and gender, both of which were independently associated with participation in physical activity.

Results

Descriptive Statistics

Table 1 shows the means and standard deviations for cardiovascular fitness, BMI, age-adjusted BMI percentile, percent body fat, and the four Actigraph® variables (using the 1953 counts/min cutoff) for the 124 adolescents included in the analyses. Compared to girls, boys had a lower BMI and BMI percentile (*p*'s < .01), lower percent body fat (*p* < .001), and higher cardiovascular fitness (*p* < .001). Boys also were more active than girls. They engaged in greater amounts of MVPA and moderate activity, and met the 60-minute criterion on more days than girls (*p*'s < .001). There was no difference between boys and girls in terms of daily vigorous activity, which was quite low in both genders. There were no differences in fitness, BMI, or body fat between those adolescents who were excluded from

[1]As an alternative approach, linear equations also were used to calculate the slope and intercept representing each individual's response to the moderate and hard exercise tasks during and after exercise, and the slope and intercept were then entered as predictors into equations testing the study hypotheses. Results of these alternative analyses were similar to those for the analyses using the affective change scores, so only the latter are presented. Analyses in which the 760 cut-point for determining physical activity was used yielded no significant associations, so results are not presented.

the analyses because they failed to complete 4 valid days of Actigraph® monitoring (including 2 weekend days) and those who were included in the analyses (data not shown). Self-reports of participation in school sports within the past year indicated that 61% of females and 46% of males had been on a school sports team in the past year.

Based on nationwide data, these adolescents appear to be representative of the general adolescent population. Growth charts published in 2000 (Kuczmarski et al., 2000) indicate that the adolescents in the present sample have a slightly higher mean BMI than the 50th percentile in 2000 (approximately 19 for boys and 19.8 for girls), which is consistent with secular trends showing a gradual increase in obesity among adolescents (Ogden et al., 2006). Similarly, the cardiovascular fitness in the present sample of adolescents appears to be slightly lower than that cited in a review published in 2002 (Eisenmann & Malina, 2002), reflecting the secular trends towards decreasing physical activity among high school freshman in the United States (Adams, 2006).

Table 2 shows the proportion of adolescents who experienced an improvement, decline, or no change in affective valence during and after exercise for the moderate- and hard-intensity exercise tasks. Based on the FS data, slightly more than half (56%) of the adolescents experienced a decline in affective valence during the moderate-intensity exercise task, 22% experienced no change, and 22% experienced an improvement in affective valence. When post-exercise affect (i.e., the average of the 30 and 40 minute assessments) was compared with pre-exercise affect, the response to the moderate-intensity exercise task was primarily positive. Only 6% of adolescents were below their baseline FS after the moderate task, and 90% were above baseline FS. For most adolescents, the affective response during the hard-intensity exercise task was negative; 85% of adolescents had a decline in affective valence, and only 9% had an improvement in affective valence. In contrast, the majority of adolescents (77%) exhibited a positive shift in affect after the hard-intensity exercise task. There was no association between gender or cardiovascular fitness and affective response during or after either the moderate- or the hard-intensity exercise task.

Exercise Task Work Rate

During the moderate-intensity exercise task, only one of the study participants was unable to maintain the target work rate (80% of the work rate at the ventilatory threshold) throughout the 30-minute exercise task. This one participant was unable to maintain a cadence of 60 rpm for a full minute resulting in a reduction in work rate of 10 watts. During the hard intensity exercise task, 83% of study participants exhibited signs of fatigue prior to the end of the 30-minute task, resulting in an average reduction in the target work rate of 33 watts per participant for these 103 individuals (range = 5-90 watts).

Effect of Exercise Intensity on Heart Rate, Rating of Perceived Exertion (RPE), and Feeling Scale (FS)

A 2 (exercise intensity: moderate and hard) X 11 (time points: baseline, minutes 3, 6, 9, 12, 15, 18, 21, 24, 27, 30) repeated measures ANOVA on the heart rate data showed a significant main effect of exercise intensity ($F(1, 94) = 479.19$, $p < .001$), a main effect of time ($F(10, 85) = 268.92$, $p < .001$), and an intensity by time interaction ($F(10, 85) = 39.05$, $p < .001$). Average heart rate increased over time in both exercise conditions, and the increase was greater during the hard exercise task.

A 2 (exercise intensity: moderate and hard) X 10 (time points: minutes 3, 6, 9, 12, 15, 18, 21, 24, 27, 30) repeated measures ANOVA on the RPE showed a significant main effect of exercise intensity ($F(1, 110) = 441.34$, $p < .001$), a main effect of time ($F(9, 102) = 58.67$, $p < .001$), and an intensity by time interaction ($F(9, 102) = 9.48$, $p < .001$). As with heart rate, average RPE increased over time in both conditions, and the increase was greater in the hard exercise task.

A 2 (exercise intensity: moderate and hard) X 5 (time points: baseline, minutes 10, 20, 30, 40) repeated measures ANOVA on the FS showed a significant main effect of exercise intensity ($F(1, 123) = 168.28$, $p < .001$), a main effect of time ($F(4, 120) = 64.38$, $p < .001$), and an intensity by time interaction ($F(4, 120) = 25.79$, $p < .001$). Adolescents' average ratings of affective valence decreased during both exercise tasks, and the decrease was more pronounced during the hard exercise task.

Association of Affective Response to Exercise with Physical Activity

Hierarchical regression was used to evaluate the association between change in FS *during* each exercise task and physical activity participation (i.e., daily MVPA, daily moderate activity, daily vigorous activity, and meeting physical activity guidelines for 60-minutes of MVPA per day) and to evaluate the association between change in FS *after* each exercise task and physical activity participation. The moderate- and hard-intensity exercise tasks were analyzed independently. All equations controlled for cardiovascular fitness and gender.

Change in affect during moderate-intensity exercise was significantly related to daily MVPA, daily moderate activity, and the proportion of days meeting the 60-minute guideline (see Table 3). The nature of the association between affective response during moderate exercise and physical activity participation was explored by examining the participation in physical activity among those who responded to moderate-intensity exercise with an improvement in affective valence, a decline in affective valence, or no change (see Table 2). Adolescents who experienced an improvement in affective valence during moderate-intensity exercise engaged in an average of 54.25 daily minutes of MVPA. In contrast, those who experienced no change in affective valence engaged in 46.94 daily minutes of MVPA, and those who experienced a decline in affective valence during moderate-intensity exercise engaged in an average of 39.83 daily minutes of MVPA. Thus, a positive change in affective valence during moderate-intensity exercise was associated with greater participation in MVPA as compared to a neutral or negative change in affective valence during moderate-intensity exercise. Moreover, adolescents who responded to moderate-intensity exercise with improved affective valence met the 60 min/day guideline on 36% of monitored days, compared to 22% among those whose affective valence declined or remained unchanged during moderate exercise. There was no association between the affective response during moderate-intensity exercise and daily vigorous physical activity, and change in affective valence *after* the moderate-intensity exercise task was not associated with physical activity participation.

There was no significant association between change in affect during the hard-intensity exercise task and physical activity participation, but the relationship between change in affect *after* the hard exercise task and physical activity participation approached significance for participation in daily vigorous activity (B(SE) = .68(.35), $p = .06$) and for the proportion of days meeting the 60-minute guideline (B(SE) = .02(.01), $p = .06$). Examination of mean levels of activity indicated that the trend was in the direction that would be expected; that is, a more positive affective response after the hard exercise task was associated with greater participation in physical activity.

Discussion

The present study was designed to examine the hypothesis that adolescents who have a positive affective shift in response to an acute exercise task would be more likely to participate in regular physical activity as compared to adolescents who have either a negative shift in affect or no change in affect in response to acute exercise. Our results support this hypothesis in that we found a significant positive association between the affective change during moderate-intensity exercise and: (a) daily MVPA; (b) daily moderate activity; and (c) the proportion of days on which adolescents engaged in at least 60 minutes of MVPA. On average, adolescents who experienced a positive shift in affective valence during moderate-intensity exercise participated in almost 15 additional daily minutes of MVPA as compared to those who experienced a decline in affective valence.

Drawing upon the dual-mode model of the affective response to exercise, we also set out to test whether the affective response to moderate-intensity exercise (i.e., below the ventilatory threshold) would be more predictive of physical activity participation than the affective response to hard-intensity exercise (i.e., above the ventilatory threshold). Consistent with our expectations, we did find that whereas the affective response during moderate-intensity exercise was positively associated with physical activity participation, the affective response during the hard-intensity exercise task was unrelated to physical activity. This finding lends support to the dual-mode model of the affective response to exercise.

We also hypothesized that the affective shift *during* exercise would be more predictive of physical activity participation than the affective response *after* exercise. In relation to moderate-intensity exercise, we did find that the affective response during exercise was associated with physical activity participation, whereas the affective response after exercise was not. This pattern is likely a function of the virtually universally positive affective response in the post-exercise period following moderate-intensity exercise. Whereas 22% of adolescents experienced a positive shift in affect during moderate-intensity exercise, 90% of adolescents experienced a positive shift in affect (compared to baseline) after the conclusion of the moderate-intensity exercise task. In relation to the hard-intensity task, however, there was a trend for the affective response after exercise to be positively associated with physical activity participation. It may be that with a larger sample or with an assessment of affect more than 10 minutes after the exercise task there would be a significant association between affective valence after hard-intensity exercise and physical activity participation. Future investigations should explore whether variability in the response after hard-intensity exercise is related to physical activity participation.

These results offer support for the theory that adolescents who find moderate exercise pleasurable will be more likely to engage in regular physical activity as compared to adolescents who do not find moderate exercise pleasurable. To our knowledge, this is the first study that has demonstrated this association using an experimental paradigm in which the affective response to a sustained bout of exercise was characterized and correlated with objectively determined participation in physical activity. That individuals differ in their affective response to exercise has been previously demonstrated (Backhouse et al., 2007; Rose & Parfitt, 2007; Welch et al., 2007), and evidence has been presented that the affective response to exercise predicts self-reported exercise participation among adults (Williams et al., 2008). Our study extends this work by examining the affective experience during a sustained moderate-intensity and hard-intensity exercise task and by assessing physical activity participation objectively, using accelerometers.

Consistent with recent theoretical and empirical work, we did find substantial variability in affective response during exercise, and the range in individual responses was considerably larger during moderate than during hard exercise. In the dual-mode model of exercise-related affect, Ekkekakis et al. (2005) have theorized that there are two independent processes that shape the affective response to exercise. One process is primarily cognitive, and may involve psychosocial factors such as self-efficacy, self-consciousness, competitiveness, or goal orientation. The other process is primarily based in physiology and includes interoceptive cues such as increased heart rate and breathing, sweating, and/or lactic acid buildup. The dual-mode model posits that during exercise at an intensity below the ventilatory threshold the affective experience will be dominated by cognitive processes, whereas during exercise that is above the ventilatory threshold the affective experience will be dominated by interoceptive processes. Certainly, studies have shown that there is far less variability in the affective response during exercise above the ventilatory threshold (Ekkekakis et al., 2005; Rose & Parfitt, 2007) and that individuals tend to become increasingly aware of their physiologic cues at higher exercise intensities (Welch et al., 2007). Thus, the limited variability in affective responding during the hard exercise task in this study is consistent with prior work and affirms the greater utility of moderate exercise as a tool for eliciting individual differences in affective responding to exercise.

This study does have limitations. First, accelerometers are often portrayed as the gold standard of physical activity assessment, owing to their objectivity, but there are limitations to their reliability. One limitation is that the wearer must remove the device while engaging in water sports, as the device is not water proof. Among an adolescent sample during summer vacation in Southern California, this limitation raises questions about the reliability of the Actigraph® data. In fact, across all 192 adolescents recruited for the study, there were 224 instances in which the Actigraph® was removed and the reason provided was a water sport. Anticipating this situation, we asked study participants to maintain a daily activity log in which they recorded any episodes during which they removed the Actigraph® to engage in water sports. When the Actigraph® data were corrected for these episodes, the results of our analyses were essentially unchanged. Thus, despite the limitations of the Actigraph® in this regard, we are confident in the reliability of our physical activity data.

Another limitation to the Actigraph® is the somewhat arbitrary choice of a cut-point for determining MVPA. The lower of the two cut-points employed in this study has been proposed for use with adults, but among adolescents this cut-point obscured the relationship between the affective response to exercise and physical activity participation. We believe that this lower cut-point may not sufficiently discriminate adolescents' volitional PA from activities of daily living; a crucial component of this study. The hedonic theory of exercise participation would be most relevant when physical activity is undertaken as a purposeful choice. Among adolescents, such volitional activity is likely to be more intense than the relatively low-intensity activities that characterize adults' lifestyle activity. We therefore conclude that the higher cut-point provided a more valid index of MVPA in this study.

Second, although we adjusted for differences in cardiovascular fitness by calibrating the exercise tasks to individual ventilatory threshold, and by including cardiovascular fitness as a covariate in our analyses, we did not control for individual differences in physical activity history. Compared to adolescents who had a history of being more active, less active individuals may have had a very different repertoire of exercise experiences upon which to draw in shaping their affective responses to the laboratory exercise. They might therefore have evaluated the increased heart rate, shortness of breath, and other physiological sensations that occur during exercise more negatively than their more active peers simply owing to their lack of familiarity with these cues. Thus, a less negative affective response exhibited by the more active adolescents during the moderate-intensity exercise task could have been an artifact of their recent experience with, and commensurate comfort level with, physical activity.

A longitudinal study of the relationship between affective response to exercise and physical activity participation among adults has reported some evidence that sedentary adults who have a more positive affective response to an exercise bout before receiving an intervention are more likely to adopt physical activity (Williams et al., 2008). Among adolescents, many of whom are regularly active, an equally important question is whether adolescents who find exercise pleasurable will be less likely to stop being active as they mature. Longitudinal research should be undertaken with adolescents to determine whether the affective response to exercise is indeed a stable individual difference that predicts behavior change.

The relationship between the affective response to exercise and physical activity participation was statistically significant, but the effect size was relatively small (3%). For each unit increase in the measure of affect used, adolescents engaged in about 4 additional minutes of MVPA daily. Physical activity is a complex behavior that is determined by multiple factors. One proposed model of adolescent physical activity (Ammouri, Kaur, Neuberger, Gajewski, & Choi, 2007) includes influencing factors from multiple domains, including individual characteristics and experiences (i.e., age, gender, BMI, race, depression symptoms), behavior-specific cognitions and affect (i.e., perceived health status, relationship with parents, parental exercise), and competing demands (i.e., screen time). A test of this model using cross-sectional survey data explained 18% of the variance in physical activity among female adolescents, with the greatest single contribution coming from girls' perceived relationship with their parents. Some portion of this effect is likely owing to shared method variance, since both the independent and the dependent variables were assessed using self-report survey methodology. Our goal in the present study was to demonstrate that the affective response to acute exercise is a factor that should be included in multidimensional models of adolescent physical activity. No doubt, the association between exercise-related affect and physical activity will be moderated by other contextual variables, so the explanatory power of the affective response to exercise may differ when other variables are included in the model. For example, adolescents who find exercising pleasant may be more likely to engage in regular MVPA if they have greater support for exercise from friends and family and/or if they have greater access to resources for being active.

The major finding of this study, that adolescents who experience a positive affective shift in response to exercise below the ventilatory threshold are more likely to participate in regular physical activity, has a number of important implications. It is possible that adolescents who find moderate exercise pleasant may be likely to seek out opportunities to be active. Conversely our results also suggest that adolescents who find moderate-intensity exercise unpleasant may be likely to engage in less physical activity. These findings suggests that exercise interventions in teens who do not find moderate activity pleasurable might wish to explore different types of activities with the potential to improve positive affect. Moderate intensity activities should target the interests of the teen, and there are increasing numbers of games for health that might encourage development of positive affect.

This study used an objective measure of physical activity participation to demonstrate that healthy adolescents who found moderate-intensity exercise pleasant engaged in more MVPA than those who found moderate- intensity exercise unpleasant or neutral. The results are consistent with the hypothesis that individuals who find exercise more aversive will engage in less physical activity, and may have implications for activity interventions. Future work in this area could extend these findings by employing in-depth interviews with adolescents during and about different types of physical activities. Such qualitative work could increase our understanding about how the cognitive factors that influence positive and negative feeling states arise and what role physical activity history, parental support and parental modeling play in the development of these cognitions.

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Table 1

Participant Characteristics M(SD).

	Boys (n = 67)	Girls (n = 57)	Full Sample (n = 124)
VO_2peak l/min **	2.77 (0.53)	2.06 (0.42)	2.44 (0.59)
VO_2peak ml/kg/min **	43.86 (6.82)	33.99 (7.19)	39.32 (8.54)
Body Mass Index kg/m^2 *	20.97 (2.73)	22.89 (3.68)	21.85 (3.34)
Body Mass Index percentile *	54.47 (27.79)	68.02 (25.41)	60.70 (27.47)
Percent Body Fat **	17.52 (6.56)	29.79 (6.39)	23.16 (8.91)
MVPA (min/day) **	53.64 (29.57)	33.79 (19.39)	44.52 (27.18)
Moderate Activity (min/day) **	47.33 (24.87)	28.97 (15.53)	38.89 (22.94)
Vigorous Activity (min/day)	6.31(7.96)	4.82(8.99)	5.63(8.45)
Proportion of days meeting 60-min criterion for MVPA **	32 (0.28)	17 (0.20)	26 (0.26)

Notes: t-tests assessed differences between genders;

* $p < .01$,

** $p < .001$

Actigraph® variables computed based on the 1953 counts/min cut-off for MVPA.

Table 2

Affective Responses During and After the Moderate and Hard Exercise Tasks.

	Improvement N (%) MVPA (SD)	No Change N (%) MVPA (SD)	Decline N (%) MVPA (SD)
During Moderate Task	27 (22) 54.25 (30.92)	27 (22) 46.94 (34.73)	70 (56) 39.83 (21.00)
After Moderate Task	112 (90) 44.68 (28.19)	5 (4) 44.62 (9.04)	7 (6) 46.80 (19.55)
During Hard Task	12 (9) 37.75 (18.05)	7 (6) 35.78 (22.28)	105 (85) 45.87 (28.26)
After Hard Task	96 (77) 45.54 (29.21)	8 (6) 50.08 (20.56)	20 (16) 37.38 (17.02)

Note: MVPA = average daily moderate-to-vigorous physical activity (min).

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Table 3

Summary of Hierarchical Regression Analysis for Affective Change during Moderate Exercise Predicting MVPA, Moderate Activity, and Proportion of Days Meeting 60 min/day Criterion (N = 124).

	MVPA			Moderate Activity			Proportion 60-min/day		
independent Variables	**B**	**SE B**	**β**	**B**	**SE B**	**β**	**B**	**SE B**	**β**
Step 1									
VO_2 peak ml/kg/min	.83*	.32	.26	.40	.27	.15	.07	.05	.17
Gender	11.66*	5.48	−.21	14.32**	4.63	−.313	−.10	.06	−.19
Step 2									
VO_2 peak ml/kg/min	.81*	.31	.25	.39	.26	.15	.06	.05	.15
Gender	11.98*	5.39	−.22	14.57**	4.57	−.31	−.11*	.06	−.20
Change in Affect	4.18*	1.83	.18	3.23*	1.55	.17	.05**	.02	.24

Note. MVPA: R^2 = .18 for Step 1; ΔR^2 = .03 for Step 2 (*p*'s < .001); Moderate Activity: R^2 = .18 for Step 1; ΔR^2 = .03 for Step 2 (*p*'s < .001); Proportion 60-min/day: R^2 = .10 for Step 1; Δ R2 = .06 for Step 2 (*p*'s < .001).

* $p < .05$,

** $p < .01$