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Impact of a personalized versus moderate-intensity exercise prescription: a randomized controlled trial

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Abstract Effective approaches to promote adolescent physical activity are needed. Moreover, a one-size-fits-all approach has been minimally successful to date. This randomized controlled trial evaluates a theory-based personalized exercise prescription to enhance motivation for being active and physical activity participation among adolescent reluctant exercisers. Adolescents were characterized by affective style as reluctant (predisposed to negative affect during exercise) or latent (predisposed to positive affect during exercise) exercisers based on their affective response to an acute exercise task, and then randomly assigned to an exercise prescription of either a personalized or a moderate intensity. Assignment was double-blind. Assessments were pre- and post- the 8-week intervention. Participants were an ethnically diverse group of adolescents (19 % non-Latino White) in a public middle-school. The exercise intensity manipulation and assessments took place at the school site during regular Physical Education. Participants were assigned to either a moderate-intensity exercise prescription [target heart rate (HR) range 60–80 % of HR max] or a personalized exercise prescription corresponding to an intensity that "feels good" to the individual for 8 weeks during daily Physical Education. Outcome measures included exercise-related intrinsic motivation (via questionnaire), and daily moderate-to-vigorous physical activity (MVPA; via accelerometer). The exercise intensity manipulation did not yield actual differences in exercise intensity during PE, and had no effect on either Intrinsic Motivation or MVPA. There was no significant interaction between affective style and group assignment in predicting Intrinsic Motivation or MVPA. This study did not find support for a link between affective experiences during exercise and physical activity participation. Providing adolescents with a personalized exercise intensity prescription and asking them to follow the prescription during PE was not an effective strategy to manipulate their affective experience of exercise. A more rigorous test of affective manipulation may require supervised exercise sessions during which exercise intensity can be directly observed and controlled.

Keywords Physical Education · School-based · Enjoyment · Exercise

Introduction

Physical activity (PA), defined as any bodily movement produced by skeletal muscles that results in energy expenditure (Caspersen et al., 1985), is a preventive behavior that protects against chronic disease. A recent meta-analysis (Lee et al., 2012) concluded that physical inactivity has an impact on population-wide life expectancy that is similar in magnitude to the impact of obesity and smoking. Moreover, inactivity and obesity are strongly linked (Aryana et al., 2012), possibly with reciprocal effects exacerbating both conditions. NHANES data indicate that 75 % of adolescents do not meet current guidelines (60 min of moderate-to-vigorous activity on most days) for activity (Fakhouri et al., 2014) and 34 % of adolescents are overweight or obese (Ogden et al., 2014). Finding effective strategies for promoting youth PA is critical for the health of the next generation.

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Recent work in physical activity promotion focuses on the role of affect as a factor influencing motivation to be physically active. Affect refers to "the most elementary consciously accessible affective feelings (and their neurophysiological counterparts) that need not be directed at anything" (Russell & Barrett, 1999, p. 806). The recent attention to affect is grounded in hedonic theory, which posits that people are motivated to engage in behaviors that bring pleasure and to avoid activities that are accompanied by feelings of displeasure (Kahneman et al., 1999; Williams, 2008). Consistent with this theory, a positive affective response to exercise (a subset of physical activity that is planned, structured, and repetitive) (Caspersen et al., 1985) correlates with PA participation (Rhodes & Kates, 2015) among both adults (Williams et al., 2008) and adolescents (Schneider et al., 2009a). The affective response to exercise also correlates with intrinsic motivation to exercise (Schneider & Kwan, 2013), which may mediate the affect-behavior relationship. Despite these findings, few intervention studies have explicitly targeted the affective experience during exercise as a means of increasing intrinsic motivation for exercise.

In a set of carefully-constructed lab-based studies, Parfitt and colleagues have explored the associations between exercise intensity and experienced affect. These studies demonstrated that women were able to regulate the intensity of their exercise to attain a designated affective state (Parfitt et al., 2012b), and that exercise intensity did not change over an 8-week training program when women were instructed to exercise at a level that felt "good" (Parfitt et al., 2012a). These studies did not investigate the impact of affect-regulated exercise on free-living physical activity or on intrinsic motivation to exercise.

Intrinsic motivation (i.e., engaging in an activity for the pleasure it provides) is a central tenet of Self-Determination Theory [SDT; (Ryan & Deci, 2000)], which posits that intrinsic motivation is generated through the satisfaction of basic psychological needs; namely, relatedness (deriving a sense of connectedness to others through the activity), autonomy (feeling that engaging in the activity engenders an internal locus of control), and competence (experiencing mastery during the activity). Indeed, there is support for SDT-informed interventions as a means of nurturing intrinsic motivation to exercise, but the modest impact on behavior suggests that additional factors should be considered as well (Owen et al., 2014). Individual exercise-associated affect is one factor that bears further examination.

Interestingly, there is substantial inter-individual variability in the acute affective response to exercise (Schneider & Graham, 2009), with some evidence that these individual differences are stable over time (Bershadsky & Schneider, 2013), partially genetically determined (Karoly et al., 2012), and predictive of future behavior (Rhodes & Kates, 2015). That a standardized acute exercise challenge can elicit divergent affective states across individuals is consistent with the dual-mode theory of exercise-associated affect (Ekkekakis et al., 2008), which posits that individuals arrive at an affective state during moderate-intensity exercise through cognitive interpretation of the interoceptive cues that accompany the exertion (e.g., increased heart rate and breathing, sweating). An individual who interprets these cues as signals of goal achievement, for example, is more likely to experience positive affect, whereas an individual who interprets these cues as signals of impending exhaustion is more likely to experience negative affect.

There are several strands of psychophysiological research that point toward potential trait-based characteristics linked with these individual predispositions. Psychologists have directed attention to the role of "approach" versus "withdrawal" motivations in determining individuals' affective interpretations of an emotion-eliciting stimulus (Carver & White, 1994) and shaping physical activity behavior (Rhodes, 2006). More specifically, adolescents who scored highly on a pencil-and paper measure of Behavioral Inhibition (a measure of sensitivity to cues of impending punishment; withdrawal motivation) evidenced more negative affect during exercise, while those who scored highly on a pencil-and-paper measure of Behavioral Activation (a measure of sensitivity to cues of impending reward; approach motivation) evidenced more positive affect during exercise (Schneider & Graham, 2009). At the same time, studies using electroencephalogram (EEG) assessments of brain activity in the frontal cortex offer support for a neurophysiological mechanism underlying individual differences in affective interpretations of emotion-eliciting stimuli (Sutton & Davidson, 1997). Among adolescents, EEG asymmetry in the frontal cortex has been linked to a more positive affective response to moderate-intensity exercise (Schneider et al., 2009b). Recent work using diffuse optical spectroscopic imaging (DOSI) to examine hemodynamic activity in the brain during exercise (Tempest et al., 2014) has further demonstrated that the affective response to an exercise challenge is associated with identifiable patterns in brain metabolism consistent with the concept of an affective style grounded in characteristic patterns of frontal cortical activity.

The identification of a characteristic predisposition to respond to exercise with either positive or negative affect creates an opportunity to tailor PA interventions according to adolescents' "affective style". Approximately half of adolescents experience negative affect in response to moderate-intensity exercise (Schneider et al., 2009a), suggesting high sensitivity to negative sensations that may accompany exercise (e.g., accumulation of lactic acid, shortness of breath). Among these "reluctant exercisers" [a term coined to describe this particular behavioral phenotype (Schneider, 2014)], an intervention that manipulates the intensity of exercise so as to decrease negative sensations and enhance the experience of positive affect during activity should be especially effective for increasing intrinsic motivation. The present study utilized a novel approach to identify an exercise intensity that generates positive affect and used this information to personalize adolescent exercise prescriptions.

We hypothesized that among reluctant exercisers a personalized exercise prescription calibrated to generate positive affect would result in greater intrinsic motivation for exercise as compared to a moderate-intensity exercise prescription, and that this increase in intrinsic motivation would result in increased time spent being physically activity throughout the whole day. A novel feature of this study is that it was implemented within a school setting and utilized regular PE classes as the channel of intervention delivery. This strategy was selected to facilitate subsequent translation and dissemination of the exercise intensity manipulation.

Methods

Procedures

Study sample

This study was conducted during four school years (2011–2015) within an ethnically diverse public middle school (50 % Latino, 24 % non-Latino White, 15 % African-American, and 8 % Asian). A new cohort was recruited each fall and followed for the full school year. Assessments took place on campus in a classroom/laboratory during Physical Education (PE) class periods. The protocol was reviewed and approved by both the University Institutional Review Board and also the Research Review Committee of the school district. Study participants provided written assent for participation, and a parent or guardian provided written consent.

Recruitment

Participants met the following inclusion criteria: (1) enrolled in the sixth grade; (2) able to participate in regular PA without restriction; (3) not currently active in a team or individual competitive sport; (4) right handed; (5) not depressed; and (6) free from a history of head trauma. The criteria targeted healthy yet non-athletic students. The last three criteria were related to the inclusion in the study protocol of a resting electroencephalogram (EEG) assessment, which was conducted as part of a study aim not addressed in this report.

Assessment schedule

Each participant visited the classroom/laboratory four times in the fall, with at least 1 week between each visit: (1) height, weight and cardiorespiratory fitness test to determine peak oxygen consumption (peak VO_2); (2) moderate-intensity exercise task; (3) exercise task at an intensity that was self-selected to feel "good"; and (4) behavioral questionnaires. Each participant also wore an ActiGraph activity monitor (model GT3X, ActiGraph, Pensacola, Florida) for seven days. The Actigraph assessment, feels-good exercise task, and behavioral questionnaires were repeated after the 8-week intervention. A $25 gift card was provided to the participant upon successful completion of each assessment.

Cardiorespiratory fitness test

Students completed a ramp-type progressive cycle-ergometer exercise test (Whipp et al., 1981). Participants were verbally encouraged to continue until they reached their limit of tolerance. Breath-to-breath measurement of gas exchange (ventilation, oxygen uptake, and carbon dioxide output) was viewed online and analyzed using a Sensor Medics® metabolic system (Yorba Linda, CA) to determine peak VO_2.

Moderate-intensity exercise task

Each participant exercised for 30 min on a stationary cycle at 50 % of the work rate at peak VO_2 and was instructed to maintain a cadence between 60 and 70 RPM. If the participant showed signs of fatigue (i.e., RPM below 60 or HR above 170 beats per minute for at least 1 min), work rate was reduced by 10 Watts. Every 3 min, a research assistant recorded HR (Polar HR monitor; Polar Electron, Lake Success, NY) and elicited self-ratings of affect [Feeling Scale (Hardy & Rejeski, 1989)]. The Feeling Scale is a single-item 11-point bipolar measure of pleasure-displeasure used to assess affective valence. Responses range from −5 (very bad) through 0 (neutral) to +5 (very good). It is only moderately related to ratings of perceived exertion, is sensitive to alterations in exercise intensity among adolescents (Sheppard & Parfitt, 2008), and is positively related to enjoyment of exercise (Robbins et al., 2006).

"Feels-Good" exercise task

To locate an exercise-intensity range associated with positive affect, students exercised for 30 min on a stationary cycle starting at 20 % of work rate at peak VO_2. Every

3 min, HR and Feeling Scale ratings were recorded and participants were invited to maintain an intensity that felt "good" by increasing or decreasing the resistance in increments of 10 watts, if desired. The specific instructions given to participants have been detailed elsewhere (Schneider, 2014). In brief, they were asked to pedal at an intensity that felt "good" to them, and were invited to increase or decrease the resistance every 3 min. Test–retest correlations of the average work rate selected during this task in the fall and then again in the spring showed good evidence of stability over time (r = .54, $p < .001$). Similarly, the test–retest correlation of the maximum heart rate reached during the feels-good task showed evidence of stability over time (r = .55, $p < .001$).

Determination of moderate-intensity and personalized heart rate prescriptions

A target HR zone was computed for each participant. The upper boundary for the moderate-intensity prescription was set at 80 % of maximum HR during the cardiorespiratory fitness test. The upper boundary for the personalized prescription was the maximum HR achieved during the "feels-good" exercise task plus ten beats per minute (pilot testing revealed that this buffer was necessary to avoid exceeding the target range by simply jogging out to the field for PE). In both conditions, the lower boundary of the HR range was 20 beats below the upper boundary.

Determination of affective style

The affective response to moderate exercise is stable across two assessments separated by a four-month period (Intraclass Correlation Coefficient = .61, $p < .01$) (Bershadsky & Schneider, 2013), thus suggesting that this response is a behavioral phenotype. Accordingly, students were categorized as either "latent" or "reluctant" exercisers on the basis of their affective response to the moderate-intensity exercise task. Those who responded with an upward trend in affect were classified as latent exercisers, whereas those who responded with a downward trend in affect were classified as reluctant exercisers. Prior research showed that adolescent latent exercisers engaged in greater amounts of free-living physical activity (Schneider et al., 2009a) and voluntarily exercised at a higher work rate when instructed to find an intensity that felt "good" (Schneider & Schmalbach, 2014).

Assignment of participants to intervention groups

Students were randomly assigned (1:1) to one of two parallel groups (the moderate-intensity or the personalized intensity) stratified by gender, body composition (body mass index above or below the 85th percentile), and affective style (latent or reluctant exercisers). Students, PE teachers, and study staff involved in the assessment procedures were all blinded to the intervention condition.

Measures

Body mass index (BMI) percentile

Height (PE-AIM-101, Perspective Enterprises, Portage, MI) and weight (Seca 869, Chino, CA) were obtained to compute BMI percentile according to the normative values provided by the Centers for Disease Control and Prevention (Centers for Disease Control and Prevention, 2012).

Self-reported screen time and sugared beverage consumption

Study participants answered 4 questions about consumption of sugar-sweetened beverages in the prior 7 days and 2 questions about the amount of time they spent on an average school day engaged with a computer or television screen. The questions were adopted from The National Youth Physical Activity and Nutrition Study [NYPANS; (Centers for Disease Control and Prevention, 2011)]. Each item assessed a distinct behavior related to the construct of interest (e.g., consumption of sodas, energy drinks, and/or sweetened teas), so the items were summed and then categorized to provide a roughly normal distribution. Beverage scores ranged from 0 (none) to 4 (at least 4) sugar-sweetened beverages in the last 7 days. Screen time scores ranged from 1 (1 h or less) to 4 (5 h or more) on an average school day.

Intrinsic motivation for exercise

Four items from the Behavioral Regulations in Exercise Questionnaire (BREQ (Mullan et al., 1997)), selected based on a factor analysis of data from 192 adolescents (Schneider & Kwan, 2013), were averaged to assess intrinsically-motivated reasons for exercising (e.g., "I exercise because it's fun"). Respondents indicated how true each item was for them on a scale of 1 (not true for me) to 7 (very true for me). Internal consistency was high in the present study (Cronbach's alpha = .80).

Physical activity

Participants wore the ActiGraph® accelerometer on the left hip for seven consecutive days, except while sleeping, swimming, or bathing. Owing to the lack of convergence in

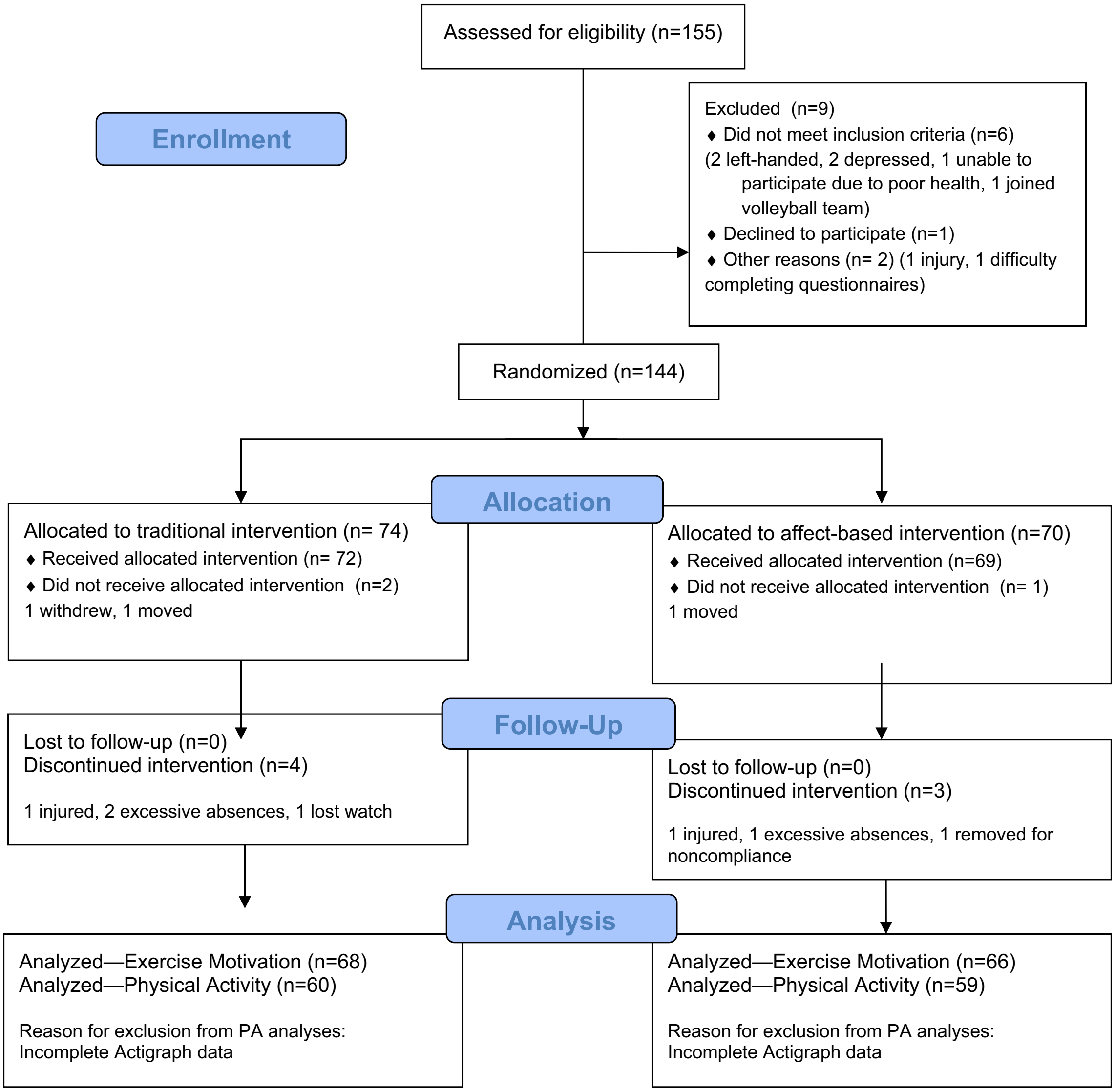

Fig. 1 CONSORT flow diagram

the literature on the ideal algorithm for use with adolescents, data from the Actigraph® were analyzed using the Actilife software with both the Freedson adult (Freedson et al., 1998) and also the Freedson Child (Freedson et al., 2005) cutoffs to yield the average number of minutes daily that participants engaged in MVPA. A valid day contained a minimum of eight valid hours of data. As per recommendations for obtaining a valid estimate of activity (Trost et al., 2005), a minimum of 4 valid days (with one weekend day) was required for a participant to be included in the analyses of average daily MVPA. Four variables were derived from the Actigraph data and analyzed separately as outcomes: (1) average daily MVPA; (2) average daily MVPA during the school day; (3) average daily MVPA after school on school days; and (4) average daily MVPA on weekend days.

Heart rate during Physical Education

Polar Heart Rate monitors (Polar Electro, Inc., Lake Success, NY) were used to assess students' heart rates during PE three times each during the 8 weeks of the exercise intensity manipulation. Each monitoring session was separated by approximately 2 weeks. Data were analyzed using Polar E Series Software (version 4.9.17) to provide the percent of wear time that each student was within the prescribed heart rate zone.

Exercise intensity manipulation

The 8-week exercise intensity manipulation commenced in January. Each student received a SmartHealth HR monitor/watch (model 22023, Salutron, Fremont, CA) programmed with the target HR determined for that student. SmartHealth watch readings correlate very highly with those of both the Polar HR monitor and electrocardiogram [$r \geq .95$; (Lee et al., 2014)]. The watch displays HR and indicates whether the wearer is "in", "hi", or "lo" relative to the programmed target HR zone. The watch does not store data. Watches were handed daily to students at the beginning of PE, and collected at its end. Students were encouraged to check their HR periodically, and to strive to stay within their assigned HR zone. PE teachers were trained to prompt students to check their HR twice during each class and to encourage students to adjust their exercise intensity to remain within their zone. PE teachers, who were encouraged to think of themselves as partners in this research effort, enabled the students to make their best effort to stay within the target HR zone they were given, regardless of whether that meant they needed to increase or decrease their activity during PE.

A feasibility study and process evaluation of the first three years of the intervention (Schneider, 2014) showed that students were able to understand and follow instructions as intended, PE teachers implemented the intervention as directed, the quality of PE instruction was similar across teachers, PE periods, and cohorts, and students made attempts to modify their activity level to stay within their target HR zone.

Data analyses

Figure 1 shows a CONSORT style flow diagram of study participation at all levels of the trial. Over the course of the study, 134 participants completed the trial (67 in the moderate-intensity group and 67 in the personalized group). Sample sizes were slightly smaller for analyses using the ActiGraph data (see Fig. 1), as post-assessment data cleaning resulted in the exclusion of students who did not meet minimum criteria for PA monitoring. Comparability between the two exercise intensity groups on key participant characteristics was examined using *t* tests, as was comparability between latent and reluctant exercisers. Differences across cohorts for all study variables were explored using ANOVA. A series of regression analyses examined the impact of the exercise intensity manipulation on the outcomes (i.e., MVPA variables and Intrinsic Motivation). To examine the potential impact of available covariates, each regression was modeled three times: Model A controlled for baseline values of the dependent variable, cohort, gender, and ethnicity (Hispanic vs non-Hispanic); Model B added BMI percentile and VO_2 peak L/min; Model C added screen time and sugared beverage consumption. Results of the 3 models did not differ in any meaningful way, so results of Model C are presented. Similarly, as results were substantively the same when analyzing MVPA data using both child and adult cutpoints, only results for the adult cutpoint are reported.

A power calculation conducted prior to the trial informed the target sample size. Based on preliminary data, we estimated that a sample size of 132 would provide 81 % power to detect an interaction between the exercise intensity type and affective style of .063 standard deviations in MVPA with a significance level of $p < .05$. All analyses were conducted using R version 3.2.4 (R Core Team, 2016).

Results

Participant characteristics

Table 1 provides baseline participant characteristics (48 % Latino, 19 % non-Latino White, 12 % African-American, 10 % Asian, 11 % multiracial/Other; 48 % male; mean age = 11.03, *SD* = .38). There were no significant differences between exercise intensity groups. Reluctant exercisers reported greater screen time compared to latent exercisers ($M = 4.0$ vs 3.0 h/day, $p < .01$). Boys had higher absolute (1.71 vs 1.56 L/min) and relative (38.73 vs 35.42 ml/kg/min) VO_2 peak compared to girls (p's $< .05$), and were more active per daily MVPA (51 min/day vs 39 min/day, $p < .001$), in-school MVPA (32 min/day vs

Table 1 Baseline participant characteristics

	All n = 134	Personalized[a] n = 67	Moderate-intensity[b] n = 67
Reluctant exerciser, n (%)	70 (52.2)	34 (50.7)	36 (53.7)
Male, n (%)	64 (47.8)	31 (46.3)	33 (49.3)
Latino, n (%)	65 (48.5)	31 (46.3)	34 (50.7)
Screen time[c], n (%)			
0–1 h/day	26 (19.4)	16 (23.9)	10 (14.9)
2–3 h/day	49 (36.6)	24 (35.8)	25 (37.3)
4 h/day	26 (19.4)	9 (13.4)	17 (25.4)
5 or more h/day	33 (24.6)	18 (26.9)	15 (22.4)
Sweetened beverages[d], n (%)			
0	15 (11.2)	9 (13.4)	6 (9.0)
1	22 (16.4)	9 (13.4)	13 (19.4)
2	36 (26.9)	21 (31.3)	15 (22.4)
3	19 (14.2)	10 (14.9)	9 (13.4)
4 or more	42 (31.3)	18 (26.9)	24 (35.8)

[a] Personalized = affect-based heart-rate prescription

[b] Moderate-intensity = moderate-intensity heart-rate prescription based on 80 % of HR max

[c] Self-reported hours of screen time on an average school day

[d] Self-reported number of sugar-sweetened beverages in the last 7 days

Table 2 Means (SD) of pre and post MVPA and intrinsic motivation, by intervention group and affective style

	Personalized intervention				Moderate-intensity intervention			
	Reluctant exercisers		Latent exercisers		Reluctant exercisers		Latent exercisers	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
MVPA ave. min/day[a]								
7-day [n = 128]	43.8 (22.4)	46.7 (24.1)	45.8 (19.9)	47.1 (20.2)	44.6 (18.4)	48.1 (21.6)	44.6 (18.0)	44.0 (25.9)
In-school [n = 126]	30.3 (12.0)	34.8 (11.3)	28.2 (8.8)	30.4 (10.3)	29.0 (8.9)	30.7 (10.7)	28.8 (10.1)	28.3 (13.1)
After-school [n = 126]	18.7 (14.1)	19.3 (18.1)	22.2 (17.8)	22.0 (15.2)	19.8 (12.1)	22.2 (17.8)	21.1 (13.4)	18.7 (13.2)
Weekend [n = 122]	27.7 (23.4)	22.7 (20.1)	38.0 (26.3)	34.2 (29.7)	33.9 (32.4)	32.8 (27.9)	30.7 (25.5)	36.9 (38.7)
Intrinsic motivation[b] [n = 134]	5.5 (1.3)	5.1 (1.6)	5.7 (1.4)	5.9 (1.4)	5.6 (1.3)	5.7 (1.4)	5.8 (1.2)	5.6 (1.4)

[a] Moderate-to-vigorous physical activity (MVPA) was derived from ActiGraph using Freedson adult cutoff (1952 counts/min). A valid day contained a minimum of 8 valid hours of data. To be included in the analyses, participants were required to have at least 4 valid days including one weekend day (7-day) or at least 3 weekday days (weekday in-school and weekday after-school) or at least one weekend day (weekend)

[b] Intrinsic motivation scores ranged from 1 to 7

26 min/day, $p < .05$), after-school MVPA (27 min/day vs 18 min/day, $p < .05$) and weekend MVPA (31 min/day vs 24 min/day, $p < .001$). Differences across cohorts for all study variables were explored using one-way ANOVA. At baseline, cohort 4 had a lower peak VO_2 than cohort 1 (mean diff. .26 L/min, $p < .01$) and cohort 2 (mean diff. .26 L/min, $p < .01$). Cohort 4 was also less active on average than cohort 2 for weekly MVPA (mean diff. 16.2 min, $p < .01$), weekday after-school MVPA (mean diff. 12.3 min, $p < .01$), and weekday during school MVPA (mean diff. 7.6 min, $p < .01$), but not for the weekend MVPA variable.

Heart rate during Physical Education

On average, heart rate was monitored for about 45 min over each PE period that students wore the Polar monitor. Averaged over the three monitored sessions, the amount of time per student spent within the prescribed heart rate zone was about 10 min (25 % of the PE period). There were no significant differences across exercise intensity groups, affective style, or the interaction between the two in terms of the amount of time spent exercising at an intensity that was within the prescribed HR range.

Impact of the intervention

Table 2 provides the means and standard deviations for each of the outcome variables by affective style and exercise intensity group over time.

Physical activity

The impact of the exercise intensity manipulation on MVPA was evaluated for four different versions of the data derived from the ActiGraph: (1) average daily MVPA; (2) average daily MVPA during school on school days; (3) average daily MVPA after school on school days; and (4) average daily MVPA on weekends. Regression analyses of each of these MVPA variables were consistent in failing to find support for an intervention effect. Comparison of estimated mean differences in post-intervention MVPA revealed no significant differences between any of the affect X intervention group combinations in comparison to the reference group (latent-moderate-intensity). The results remained the same after covariates were entered into the equation to control for baseline MVPA, cohort, gender, ethnicity, BMI percentile, VO_2 peak L/min, screen time, and sugared beverage consumption.

Intrinsic motivation

In the regression analysis predicting IM, the estimated mean differences in post-intervention IM after controlling for baseline MVPA, cohort, gender, ethnicity, BMI percentile, VO_2 peak L/min, screen time, and sugared beverage consumption were statistically no different for any of the groups as compared to the reference group (latent-moderate-intensity). The exercise intensity manipulation had no impact on IM.

Discussion

A randomized controlled trial evaluated the efficacy of a personalized exercise intensity manipulation to promote physical activity motivation and participation among adolescents who were classified, based on their affective response to moderate-intensity exercise, as latent or reluctant exercisers. Results failed to support the hypothesis that reluctant exercisers would derive greater motivational benefit from the personalized exercise intensity intervention. No differences in Intrinsic Motivation or MVPA were observed for any of the affective style-exercise intensity pairings in relation to the reference group (latent-moderate-intensity).

This study builds on earlier work investigating the role of affect in PA behavior. A systematic review of the PE intervention literature published between January 1990 and June 2010 (Dudley et al., 2011) found 7 articles with enjoyment of activity as an outcome. Only one of these studies reported a positive impact on enjoyment, and the authors concluded that "a lack of high quality evaluations and adequate statistical power hampers conclusions concerning the effectiveness of interventions to improve enjoyment of physical activity in [physical education and school sport] (p. 374)". A recent review of the research linking exercise-associated affect and PA concluded that "experimental tests that attempt to manipulate the affective experience during exercise and its impact on sustained behavior change and enjoyment… are now needed (p. 728)"(Rhodes & Kates, 2015). The current study addresses this knowledge gap and provides useful information for future investigations into the role of exercise intensity manipulation as a means of improving the affective experience associated with exercise.

The emphasis on IM as an important indicator of program success was grounded in the results of a critical mass of studies. A review of 66 studies supported the assumption that IM predicts MVPA among adults (Teixeira et al., 2012), and a review of 46 studies confirmed this association among adolescents (Owen et al., 2014). One recent study in particular found that adolescents' changes in IM predicted MVPA in a 2-year intervention study (Quaresma et al., 2014). On the basis of these studies we set out to establish whether personalizing the exercise intensity to maximize positive affect would enhance IM. In the end, however, the exercise intensity manipulation was not effective, the reasons for which we examine below.

The affective manipulation did not have an impact on adolescents' IM or physical activity behavior. The heart rate data collected during PE classes, however, suggest that it would be premature to conclude that an affective manipulation of the exercise experience will not result in changes in physical activity behavior over the long term. In the present study, students were only able to keep their heart rate within their personally-prescribed range for 10 min out of every PE class, meaning that for the majority of the time they were exercising at a heart rate that was outside their prescribed range. Our attempts to restrict exertion to within a zone that felt "good" to individuals were not successful. The methods were developed to maximize ecological validity and promote the translatability of the findings to PE instruction, but it appears that in order to demonstrate a causal link between changes in exercise-associated affect and self-directed physical activity behavior a preliminary step may be necessary in which the exercise-associated affective experience is more carefully controlled. A lab-based study using supervised exercise intensities and tracking both exercise-associated affect and free-living MVPA over time may be a necessary step to test the hypothesis that physical activity participation can be encouraged by improving the affective experience of individual exercise bouts. Such a controlled study also would permit a closer analysis of the temporal and situational stability of the affective response to exercise. In the current study, heart rates during the feels-good task demonstrated only moderate stability over time, which may suggest that heart rate is not the best criterion upon which to recommend an affect-based exercise intensity.

It is worth noting that in this sample of study participants there was no difference in baseline MVPA by affective style. This finding is inconsistent with earlier work among adolescents (Schneider et al., 2009a) showing that latent exercisers engaged in more MVPA compared to reluctant exercisers. A likely explanation for this discrepancy is the exclusion criteria applied in the present study. Adolescents who were members of a sports team or competed in individual sports were excluded from the present study. It is quite possible that if athletic students had been included in the present study the relative impact of the personalized intervention on reluctant exercisers would have been more pronounced. Future studies may be well-advised to include the full range of PA participation when investigating the impact of affective style on PA behavior.

The absence of any impact on MVPA in the present study should be interpreted within the context of the younger adolescent lifestyle, environment and developmental stage. All of these students were in the sixth grade during the study, and thus at an age when most youth are still relatively active (average MVPA was about 45 min/day). Moreover, these students had the benefit of a high-quality PE program that was more effective than most in keeping students active during the PE period (Schneider, 2014). Finally, middle-school students' activities are still largely constrained by parental influence, with increasing independence of behavioral choice emerging as students mature. Thus, it may be that an impact of the exercise intensity manipulation on behavior will emerge on a longer time course as students become more autonomous and have the freedom and ability to make their own choices regarding being physically active.

Limitations

The internal validity of the study is bolstered by the double-blind random assignment, which is very unusual in behavioral studies. Because students were provided with a target HR range and were not informed as to how that range was derived, they did not know whether they had been assigned to the personalized or the traditional exercise intensity manipulation. Similarly, study staff and PE teachers were blind to assignment conditions. Limitations to the study include the relatively short follow-up. It is possible that affective manipulations take a longer time to have an impact on behavioral choices. In addition, although we successfully recruited our target sample size as dictated by the a priori power analysis, the loss of some participants to analysis as a result of missing ActiGraph data meant that the analysis of the impact of the intervention on MVPA was under-powered. The major limitation to the study was the failure of the intensity manipulation. Study participants, in effect, did not undergo the affective experience that was intended. Future studies should include tracking of PA across a longer time period to determine the long-term impact of personalized interventions, should inflate recruitment to account for incomplete activity monitoring data, and should build in real-time validation of exercise intensity to ensure the intensity manipulation is delivered as intended.

Conclusions

This study was unable to provide support for the hypothesis that adolescent PA could be enhanced through a manipulation of exercise intensity prescriptions because youth did not maintain a hear rate within their prescribed range for more than about 25 % of the PE period. To definitively test this hypothesis, it may be necessary to step back into the lab and use supervised exercise sessions as a means of shifting adolescent's affective perceptions in relation to exercise.

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Compliance with ethical standards

Conflict of interest Margaret Schneider, Priel Schmalbach, and Sophia Godkin declare that they have no conflict of interest.

Human and animal rights and Informed consent All procedures followed were in accordance with ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2000. Informed consent was obtained from all patients for being included in the study.

References

Aryana, M., Li, Z., & Bommer, W. J. (2012). Obesity and physical fitness in California school children. *American Heart Journal, 163*, 302–312. doi:10.1016/j.ahj.2011.10.020

Bershadsky, S., & Schneider, M. (2013). *Affective response to exercise and physical activity among adolescents: Moderation by consistency and stability of the affective response to exercise*. Paper presented at the society of behavioral medicine annual meeting, San Francisco.

Carver, C. S., & White, T. L. (1994). Behavioral inhibition, behavioral activation, and affective responses to impending reward and punishment: The BIS/BAS Scales. *Journal of Personality and Social Psychology, 67*, 319–333.

Caspersen, C. J., Powell, K. E., & Christenson, G. M. (1985). Physical activity, exercise, and physical fitness: Definitions and distinctions for health-related research. *Public Health Reports, 100*, 126–131.

Centers for Disease Control and Prevention. (2011). Fruit and vegetable consumption among high school students–United States, 2010. *Morbidity and Mortality Weekly Report, 60*, 1583–1586.

Centers for Disease Control and Prevention. (2012). BMI percentile calculator for child and teen English version. http://nccd.cdc.gov/dnpabmi/Calculator.aspx

Dudley, D., Okely, A., Pearson, P., & Cotton, W. (2011). A systematic review of the effectiveness of physical education and school sport interventions targeting physical activity, movement skills and enjoyment of physical activity. *European Physical Education Review, 17*, 353–378. doi:10.1177/1356336x11416734

Ekkekakis, P., Hall, E. E., & Petruzzello, S. J. (2008). The relationship between exercise intensity and affective responses demystified: To crack the 40-year-old nut, replace the 40-year-old nutcracker! *Annals of Behavioral Medicine, 35*, 136–149. doi:10.1007/s12160-008-9025-z

Fakhouri, T. H., Hughes, J. P., Burt, V. L., Song, M., Fulton, J. E., & Ogden, C. L. (2014). Physical activity in U.S. youth aged 12-15 years, 2012. *NCHS Data Brief, 141*, 1–8.

Freedson, P. S., Melanson, E., & Sirard, J. (1998). Calibration of the Computer Science and Applications, Inc. accelerometer. *Medicine and Science in Sports and Exercise, 30*, 777–781.

Freedson, P., Pober, D., & Janz, K. F. (2005). Calibration of accelerometer output for children. *Medicine and Science in Sports and Exercise, 37*, S523–S530.

Hardy, C. J., & Rejeski, W. J. (1989). Not what, but how one feels: The measurement of affect during exercise. *Journal of Sport and Exercise Psychology, 11*, 304–317.

Kahneman, D., Diener, E., & Schwarz, N. (1999). *Well-being: The foundations of hedonic psychology*. New York: Russell Sage Foundation.

Karoly, H. C., Stevens, C. J., Magnan, R. E., Harlaar, N., Hutchison, K. E., & Bryan, A. D. (2012). Genetic influences on physiological and subjective responses to an aerobic exercise session among sedentary adults. *Journal of Cancer Epidemiology, 2012*, 540563. doi:10.1155/2012/540563

Lee, J. M., Kim, Y., & Welk, G. J. (2014). Validity of consumer-based physical activity monitors. *Medicine and Science in Sports and Exercise, 46*, 1840–1848. doi:10.1249/MSS.0000000000000287

Lee, I. M., Shiroma, E. J., Lobelo, F., Puska, P., Blair, S. N., Katzmarzyk, P. T., et al. (2012). Effect of physical inactivity on major non-communicable diseases worldwide: An analysis of burden of disease and life expectancy. *Lancet, 380*, 219–229. doi:10.1016/S0140-6736(12)61031-9

Mullan, E., Markland, D., & Ingledew, D. K. (1997). A graded conceptualisation of self-determination in the regulation of exercise behaviour: Development of a measure using confirmatory factor analytic procedures. *Personality and Individual Differences, 23*, 745–752. doi:10.1016/S0191-8869(97)00107-4

Ogden, C. L., Carroll, M. D., & Flegal, K. M. (2014). Prevalence of obesity in the United States. *JAMA, 312*, 189–190. doi:10.1001/jama.2014.6228

Owen, K. B., Smith, J., Lubans, D. R., Ng, J. Y. Y., & Lonsdale, C. (2014). Self-determined motivation and physical activity in children and adolescents: A systematic review and meta-analysis. *Preventive Medicine, 67*, 270–279. doi:10.1016/j.ypmed.2014.07.033

Parfitt, G., Alrumh, A., & Rowlands, A. V. (2012a). Affect-regulated exercise intensity: Does training at an intensity that feels 'good' improve physical health? *Journal of Science and Medicine in Sport, 15*, 548–553. doi:10.1016/j.jsams.2012.01.005

Parfitt, G., Blisset, A., Rose, E. A., & Eston, R. (2012b). Physiological and perceptual responses to affect-regulated exercise in healthy young women. *Psychophysiology, 49*, 104–110. doi:10.1111/j.1469-8986.2011.01287.x

Quaresma, A. M., Palmeira, A. L., Martins, S. S., Minderico, C. S., & Sardinha, L. B. (2014). Effect of a school-based intervention on physical activity and quality of life through serial mediation of social support and exercise motivation: The PESSOA program. *Health Education Research, 29*, 906–917. doi:10.1093/her/cyu056

R Core Team. (2016). R: A language and environment for statistical computing. 2016, from http://www.R-project.org/

Rhodes, R. E. (2006). The built-in environment: The role of personality and physical activity. *Exercise and Sport Science Reviews, 34*, 83–88.

Rhodes, R. E., & Kates, A. (2015). Can the affective response to exercise predict future motives and physical activity behavior? A systematic review of published evidence. *Annals of Behavioral Medicine, 49*, 715–731. doi:10.1007/s12160-015-9704-5

Robbins, L. B., Gretebeck, K. A., Kazanis, A. S., & Pender, N. J. (2006). Girls on the move program to increase physical activity participation. *Nursing Research, 55*, 206–216.

Russell, J. A., & Barrett, L. F. (1999). Core affect, prototypical emotional episodes, and other things called emotion: Dissecting the elephant. *Journal of Personality and Social Psychology, 76*, 805–819.

Ryan, R. M., & Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist, 55*, 68–78.

Schneider, M. (2014). Process evaluation and proximal impact of an affect-based exercise intervention among adolescents. *Translational Behavioral Medicine, 4*, 190–200.

Schneider, M., Dunn, A., & Cooper, D. (2009a). Affect, exercise, and physical activity among healthy adolescents. *Journal of Sport and Exercise Psychology, 31*, 706–723.

Schneider, M., & Graham, D. (2009). Personality, physical fitness, and affective response to exercise among adolescents. *Medicine and Science in Sports and Exercise, 41*, 947–955. doi:10.1249/MSS.0b013e31818de009

Schneider, M., Graham, D., Grant, A., King, P., & Cooper, D. (2009b). Regional brain activation and affective response to physical activity among healthy adolescents. *Biological Psychology, 82*, 246–252. doi:10.1016/j.biopsycho.2009.08.003

Schneider, M., & Kwan, B. (2013). Psychological need satisfaction, intrinsic motivation and affective response to exercise in adolescents. *Psychology and Sport in Exercise, 14*, 776–785. doi:10.1016/j.psychsport.2013.04.005

Schneider, M., & Schmalbach, P. (2014). Affective response to exercise and preferred exercise intensity among adolescents. *Journal of Physical Activity & Health*. doi:10.1123/jpah.2013-0442

Sheppard, K. E., & Parfitt, G. (2008). Acute affective responses to prescribed and self-selected exercise intensities in young adolescent boys and girls. *Pediatric Exercise Science, 20*, 129–141.

Sutton, S. K., & Davidson, R. J. (1997). Prefrontal brain asymmetry: A biological substrate of the Behavioral Approach and Inhibition Systems. *Psychological Science, 8*, 204–210.

Teixeira, P. J., Carraca, E. V., Markland, D., Silva, M. N., & Ryan, R. M. (2012). Exercise, physical activity, and self-determination theory: A systematic review. *International Journal of Behavioral Nutrition and Physical Activity*. doi:10.1186/1479-5868-9-78

Tempest, G. D., Eston, R. G., & Parfitt, G. (2014). Prefrontal cortex haemodynamics and affective responses during exercise: A multi-channel near infrared spectroscopy study. *PLoS One, 9*, e95924. doi:10.1371/journal.pone.0095924

Trost, S. G., McIver, K. L., & Pate, R. R. (2005). Conducting accelerometer-based activity assessments in field-based research. *Medicine and Science in Sports and Exercise, 37*, S531–S543.

Whipp, B. J., Davis, J. A., Torres, F., & Wasserman, K. (1981). A test to determine parameters of aerobic function during exercise. *Journal of Applied Physiology, 50*, 217–221.

Williams, D. M. (2008). Exercise, affect, and adherence: An integrated model and a case for self-paced exercise. *Journal of Sport and Exercise Psychology, 30*, 471–496.

Williams, D. M., Dunsiger, S., Ciccolo, J. T., Lewis, B. A., Albrecht, A. E., & Marcus, B. H. (2008). Acute affective response to a moderate-intensity exercise stimulus predicts physical activity participation 6 and 12 months later. *Psychology of Sport and Exercise, 9*, 231–245. doi:10.1016/j.psychsport.2007.04.002